NOAA Deep Sea Coral Research and Technology Program Southeast Deep Coral Initiative (SEDCI) 2016-2019: Final Report

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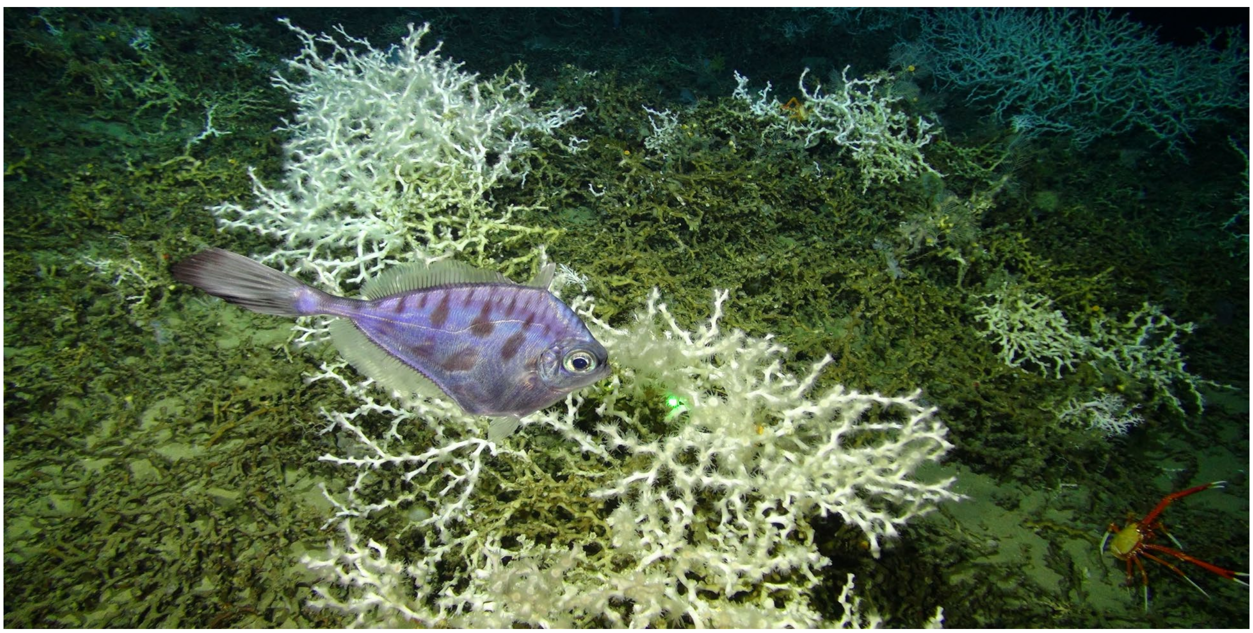

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NOAA Deep Sea Coral Research and Technology Program Southeast Deep Coral Initiative (SEDCI) 2016-2019: Final Report

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Cover image: Thorny tinselfish swimming above dense *Lophelia pertusa* coral mounds discovered at 500 meters depth on the West Florida Slope. Image: NOAA, Pelagic Research Services.

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Acknowledgments

Special thanks and acknowledgment to all those who contributed to this initiative including scientists, managers, and staff at the Deep Sea Coral Research and Technology Program, Office of Ocean Exploration and Research, National Centers for Coastal Ocean Science, Southeast Fisheries Science Center, and Office of National Marine Sanctuaries.

Deep respect as well to Woods Hole Oceanographic Institution, The Global Foundation for Ocean Exploration, University of North Carolina - Wilmington Underwater Vehicles Program, and Pelagic Research Services for operation of AUV *Sentry*, HOV *Alvin*, and ROVs *Deep Discover*, *Mohawk*, and *Odysseus*, respectively.

Executive Summary

In 2016, the National Oceanic and Atmospheric Administration (NOAA) Deep Sea Coral Research and Technology Program (DSCRTP) initiated a four-year research initiative, referred to as the Southeast Deep Coral Initiative (SEDCI), in the U.S. Southeast region. This project area encompassed the Caribbean, Gulf of Mexico, and South Atlantic Fishery Management Council regions. The total DSCRTP funding for initiative activities was $2.5 M over four years.

This report details activities undertaken between 2016-2019, including 21 expeditions on five research vessels and a dozen small projects. Small projects produced an online geodatabase, photo identification guides, habitat suitability models, and environmental monitoring projects. Research plans were developed in consultation with the Caribbean, Gulf of Mexico, and South Atlantic Fishery Management Councils. The research was made possible through important partnerships, including with numerous NOAA offices and programs, other federal agencies, NOAA cooperative institutes, and academic partners.

Key science achievements through the partnership that advanced our understanding of deep-sea coral and sponge ecosystems in the region include the following:

1) Discovery, mapping, and characterization of coral habitats of the Blake Plateau, including the most extensive region of deep-sea coral reefs in U.S. waters
2) The first surveys of deep-sea corals and sponges in the Carolina submarine canyons
3) Improved characterizations of deep-sea coral and sponge communities in the Gulf of Mexico, particularly in the Flower Garden Banks region and the West Florida Slope
4) Discovery of a new species of black coral
5) Collaboration with fishermen in Puerto Rico to document habitat, fish diversity, and benthic invertebrates at 471 locations where the deepwater snapper fishery is active
6) Generation of 81,000 deep-sea coral and sponge records added to NOAA's National Database of Deep-Sea Corals and Sponges
7) Publication of scientific research in eight journal articles, eight NOAA Technical Memoranda, and seven academic theses

Major outcomes that were informed by SEDCI research teams in the Gulf of Mexico included designation of 21 new Habitat Areas of Particular Concern for deep-sea corals (13 of which have restrictions on bottom fishing) and expansion of the Flower Garden Banks National Marine Sanctuary. Major outcomes in the U.S. Caribbean included a telepresence cruise that engaged scientists ashore, dedicated sampling of mesophotic coral species for taxonomic research, and the first set of habitat suitability models for deep-sea corals in the U.S. Caribbean. In the Southeast U.S., SEDCI facilitated several more telepresence cruises, and acquired years of unpublished seafloor observations from regional partners going back to 1988. SEDCI also partially supported a collaborative cruise using human-occupied vehicle *Alvin*, which provided new insights into the vast extent of branching stony corals on the Blake Plateau - over 85-miles of *Lophelia pertusa* reefs and mounds!

It is perhaps equally important that throughout the initiative, SEDCI supported many talented undergraduate and graduate students conducting seven Masters thesis projects, and producing 16 scientific publications to date. More results from SEDCI are expected to be released as these data resources are further analyzed and used by fishery management councils and other partners in coming years.

1. Introduction

1.1 Overview

The National Oceanic and Atmospheric Administration (NOAA) established the Deep Sea Coral Research and Technology Program (DSCRTP) under the authority of the Magnuson-Stevens Fishery Conservation and Management Act, as reauthorized in 2007. The goal of the DSCRTP is to provide scientific information needed to manage and protect deep-sea coral and sponge ecosystems throughout the United States. To achieve this mission, the DSCRTP works with partners to support multi-year regional fieldwork initiatives and targeted projects centered on conducting new research, assimilating historic data, and making results public in support of deep-sea coral and sponge ecosystem management. This report presents the results to date of the DSCRTP's four-year Southeast Deep Coral Initiative (referred to as SEDCI or "Initiative").

This report begins with a review of the original activities that shaped the Initiative – a 2015 priority-setting workshop held in St. Petersburg, Florida, attended by 31 scientists and resource managers (Schull et al., 2016), followed by a science plan published by NOAA to address these priorities (Wagner et al., 2016).

The report then shows highlights from the Initiative, such as management implications, partnerships, student participation, and outreach. The following highlights are summaries of the fieldwork and small project activities that were funded by the Initiative. These summaries were written by the principal investigator (PI) or lead for each activity. The report concludes with a list of future administrative and scientific priorities as recorded by the SEDCI Science Team, a list of the products from Initiative-funded activities, and a breakdown of the Initiative expenditures.

1.2 Retrospective Review of SEDCI Science Plan and its Execution

1.2.1 Priority Information for Management Identified by the Councils and Other Entities

In 2015, SEDCI workshop attendees were asked to list and rank fishery management council (FMC) priorities and scientific research questions for each of the three study regions (Schull et al., 2016) to help guide the initiative. These priorities and questions were used to develop the SEDCI Research Plan (Wagner et al., 2017). Key priorities for each region are shown in bold below, with yes and no answers for those priorities on which substantial progress was made, and brief details on the project's approach to their execution.

Caribbean

Collaborate with local fishers to characterize habitats for deepwater snappers and groupers* - *Yes. SEDCI supported a 3-year cooperative research project by Kate Overly of NOAA Fisheries, to collaborate with local fishermen to deploy drop cameras in hundreds of sites across Puerto Rico. See Section 3.4.3 for details.

Analyze pre-existing video data* - *Yes. SEDCI supported a data-rescue project by Matt Poti and Tim Battista of the NOAA National Centers for Coastal Ocean Science (NCCOS), to review remotely operated vehicle (ROV) video collected since 2003. The data were made public through NOAA's National Database of Deep-Sea Corals and Sponges. See Section 4.5 for details.

Gulf of Mexico

Inform expansion of the Flower Garden Banks National Marine Sanctuary (FGBNMS) - Yes. This expansion went into effect in January of 2021. FGBNMS received funding for three years to conduct benthic surveys aboard R/V *Manta* with ROV *Mohawk*, and support graduate student, Travis Sterne, at TAMU-Galveston to model habitat suitability in proposed expansion areas. See Section 3.2.1 for details.

Inform establishment of new deepwater Habitat Areas of Particular Concern (HAPCs) - Yes. The Gulf of Mexico Fishery Management Council's Amendment 9 to the Fishery Management Plan for Coral and Coral Reef Resources in Gulf of Mexico incorporated SEDCI-analyzed data from several cruises. In particular, the 2017 SEDCI field expedition aboard NOAA Ship *Nancy Foster* contributed new information that resulted in an updated and significantly expanded proposal for the West Florida Wall HAPC, one of 13 HAPCs protected from fishing impacts as of 2020. See Sec. 3.2 for details.

South Atlantic

Prioritize these areas: National Marine Sanctuaries (NMS), and Council-established Marine Protected Areas (MPAs) and potential deepwater HAPCs - No for NMS in the Southeast region, unfortunately. ***Yes for MPAs and potential HAPCs.*** Many new ROV and submersible dives were conducted both inside and outside potential HAPCs (under consideration at the time) through NOAA Office of Ocean Exploration and Research (OER) and Bureau of Ocean Energy Management's (BOEM) DEEP SEARCH (Deep Sea Exploration to Advance Research on Coral/Canyon/Cold seep Habitats) campaign as well as NOAA Ship *Okeanos Explorer* expeditions, all supported in part by SEDCI. Additionally, SEDCI supported the data rescue and analysis of 10 years of coral and sponge observations inside and outside the shelf edge MPAs, conducted by Southeast Fisheries Science Center (SEFSC) with Harbor Branch Oceanographic Institute (HBOI, at Florida Atlantic University). The MPA cruises were funded by the Coral Reef Conservation Program, which required reports, not raw data. These data are all now available on https://deepseacoraldata.noaa.gov/. See Sec. 3.3 and 4.5 for details.

Access information to support the establishment of five Spawning Special Management Zones (SMZs) - Yes. The data rescue noted above included observations inside and outside four of the five proposed Spawning SMZs. The SMZs became effective July 31, 2017. See Sec. 4.5 for details.

Map and characterize areas where deepwater coral ecosystems exist, and understand the extent of fishing efforts in these areas. - Yes and No. NOAA Ship *Nancy Foster* expedition NF-17-08, NOAA Ship *Pisces* 17-04 and NOAA OER conducted expeditions in 2018 and 2019, including new mapping, and SEDCI has characterized the coral ecosystems discovered (See Sec. 3.3). SEDCI, however, did not analyze fishing effort in these areas.

1.2.2 Priorities for Science

The list of research questions for each region are provided below, from the SEDCI Science Plan (Wagner et al., 2016). Answers to these types of questions can be detailed and complicated. Questions that were not addressed directly through SEDCI-sponsored activities and partnerships have been included in Section 8 Future Considerations, to be addressed at a later time. Other questions were driven, or satisfied, by SEDCI-sponsored activities.

Caribbean

Where are deep-sea coral and sponge ecosystems located? Large aggregations of gorgonians and sponges were found between 50-150 m depth range off St Croix, St. Thomas, and southwest Puerto Rico. Scattered coral colonies were observed as deep as 4,998 m by NOAA OER onboard NOAA Ship *Okeanos Explorer* aboard cruises EX1502L3 (in data analyzed by SEDCI) and EX1811 Oceano Profundo (in collaboration with SEDCI). The types of corals at these depths were mostly black corals, bamboo corals, and sea pens. Branching stony corals (*Madrepora* and *Enallopsammia*) were observed as deep as 1,200 and 850 m, respectively, but not in great abundance. Glass sponges (Hexactinellida) and carnivorous Cladorhizidae sponges were common in these sparse communities. See Sec. 3.4 for details.

Do deep-sea coral ecosystems exist in areas fished for deepwater snappers? Yes. This was studied in partnership with fishermen along the coast of Puerto Rico, from depths of 100-500 m. Deepwater snapper, including queen snapper (*Etelis oculatus*), silk snapper (*Lutjanus vivanus*), blackfin snapper (*Lutjanus buccanella*), vermilion snapper (*Rhomboplites aurobens*), wenchman snapper (*Pristipomoides aquilonaris*) and cardinal snapper (*Pristipomoides macrophthalmus*), were found to co-occur with deep-sea corals. The survey recorded data at 471 survey sites, with 25% of sites documenting a minimum of one deep-sea coral or sponge species. In total, 17% of survey sites had both deep-sea coral ecosystems and deepwater snappers. See Sec. 3.4.3 for details.

What are the most significant anthropogenic impacts to deep-sea coral and sponge ecosystems, particularly at mesophotic depths? An attempt was made to examine offshore dredge spoils, but ultimately this question was not directly addressed during SEDCI.

Gulf of Mexico

What sites could serve as sentinel sites to better understand the effects of climate change? Sites with a long history of climate records that include long-lived colonies that are useful as environmental proxies. Climate records are generally available from the Bermuda Atlantic Time Series, and water flows from the Mississippi River. The colonies most useful as environmental proxies are *Leiopathes* black corals, gorgonian octocorals, or *Stylaster* hydrocoral colonies. See Sec. 4.4 for details.

Which seafloor features in the northern Gulf of Mexico need mapping, ground-truthing and characterization? Mound features and basins in the northwestern Gulf of Mexico and Blake Plateau. Rocky escarpment features at 400 m and 1800 m along West Florida Shelf and Slope.

What is the connectivity between coral ecosystems at different depths? Ecological and genetic connectivity appear to be relatively low across depth zones. Communities are more connected across distance, according to research by Bracco et al. (2019). SEDCI provided supplemental funding to the RESTORE (Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies) Act affiliated project, 'Population Connectivity of Deep Coral Ecosystems,' led by Santiago Herrera (Lehigh University), with Annalisa Bracco (University of Georgia), Andrea Quattrini (Smithsonian National Museum of Natural History), and Peter Etnoyer (NOAA). See Sec. 3.1.4 for details.

How accurate are existing habitat suitability models? No formal validation analysis of the original NCCOS Gulf of Mexico models (Kinlan et al., 2013) has yet been conducted. However, aspects of the SEDCI modeling can inform existing modeling projects and future research.

First, the original models were used to contribute to SEDCI survey design in some limited cases when people asked for support. The first step in validating those models would be to use the models to target collection of new data.

Second, those new data contributed to new models including the *Leiopathes* model from Etnoyer et al., 2018, and the BOEM Gulf of Mexico models. These new models are improvements upon the old models. So, while not a validation of the old models per se, the old models did contribute to a process whereby new improved models were created.

Proper rigorous validation of the original models would require an independent and extensive validation dataset. Although that didn't occur during SEDCI, we are hoping to integrate a more dedicated validation element in the modeling that will be completed during the National Resource Damage Assessment Mesophotic and Deep Benthic Community restoration project. The large scope and long timeline of those projects provides a great opportunity to build the feedback between modeling and new data collection more explicitly in the plan.

What drives community differences in low vs. high-relief habitats? These analyses have not been done, but the information collected by SEDCI partners may be appropriate and sufficient to analyze and provide some answers to this question for some sites. See Section 3.2.3 for details.

Southeast U.S.

How do communities differ inside and outside of MPAs? Although this question was targeted at the Southeast U.S., it was studied in a few regions. In the western Gulf of Mexico, FGBNMS staff surveyed areas within and between proposed Sanctuary expansion areas. In the eastern Gulf of Mexico, SEDCI surveyed areas within and between proposed HAPCs. This work led the Gulf Council to expand proposed boundaries for the West Florida Wall HAPC, as large *Lophelia* aggregations were documented between originally proposed areas. In the Southeast U.S., large numbers of *Swiftia* octocorals occur outside of Edisto MPA, compared to inside. One single dive outside the MPA documented 1736 colonies while the three dives conducted inside had 9, 21, and 83 colonies. See Sec. 3.3.1, 3.3.2, and 4.5 for details.

What topographic features are associated with deep-sea coral communities? Mound features in the 500-800 m depth range on Blake Plateau are often associated with dense cover of branching stony corals. Canyon features revealed some coral gardens of bubblegum and bamboo corals. See Sec. 3.3.2 for details.

How accurate are deep-sea coral habitat suitability models, particularly for structure-forming taxa? DEEP SEARCH collaborators found that the resolution of initial 2012 NOAA models were insufficient to predict suitable habitat for *Lophelia* in unmapped areas of the seafloor along Blake Plateau. Multibeam echosounder systems are necessary to reveal these features. See Sec. 3.1.4 and 3.3.2 for details.

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2. Highlights of the Four-Year Initiative

2.1 Fieldwork Accomplishments

SEDCI contributed to 21 research expeditions from 2016-2019 by providing funding or scientific staff, and analysis of the coral and sponge fauna across the Southeast U.S., Gulf of Mexico and U.S. Caribbean. These expeditions and subsequent data analysis by SEDCI are advancing our understanding of deep-sea coral ecosystems in the regions and are already finding application by informing management action (see Section 7). Data analysis is continuing, but initial highlights and discoveries include the following:

- SEDCI participated in three expeditions and 35 ROV dives in the Southeast region in partnership with OER and NOAA Ship *Okeanos Explorer*, and one DEEP SEARCH submersible expedition with BOEM and U.S. Geological Survey (USGS). Mapping and ROV surveys on the Blake Plateau revealed an exceptional deep-sea scleractinian coral mound province – which may represent the largest such coral mound province in the Atlantic Ocean, if not the world. We are providing this information to the South Atlantic Fishery Management Council, including areas of deep-sea coral reefs that lie outside the current HAPC boundaries.
- Conducted the first surveys of deep-sea corals and sponges in the Carolina submarine canyons. Similar canyon systems to the north have been the focus of recent deep-sea coral protected areas by the New England and Mid-Atlantic Fishery Management Councils.
- Conducted five expeditions and 111 ROV dives, which helped characterize coral and sponge ecosystems of banks in the Northwest and Central Gulf of Mexico in partnership with the Flower Garden Banks National Marie Sanctuary. This information, along with associated predictive habitat models, contributed to the successful expansion of the Sanctuary.
- Provided key information on deep coral habitats in the Gulf of Mexico through two major NOAA Ship *Okeanos Explorer* expeditions and a SEDCI-led expedition on NOAA Ship *Nancy Foster*. The new observations and analyses contributed to the establishment of new HAPCs by the Gulf of Mexico Fishery Management Council.
- Documented habitat, fish diversity, and benthic invertebrates at 471 locations where the deepwater snapper fishery is active, working collaboratively with fishermen in Puerto Rico. This information will help describe habitat use by queen snapper and potential linkages with deepwater coral communities.
- Mapped and collected baseline information on deep-sea coral and sponge habitats at depths from 15 m to 5,000 m around Puerto Rico and the U.S. Virgin Islands, through two partnerships aboard NOAA Ship *Nancy Foster* and an expedition on *Okeanos Explorer*.
- SEDCI added over 81,000 deep-sea coral and sponge records to NOAA's National Database of Deep Sea Corals and Sponges – many with associated images.
- Discovered and described one new black coral species, and made three new species guides
- Produced scientific results from SEDCI research that have already been featured in eight journal articles, eight NOAA Technical Memoranda, and seven academic theses.

2.2 Management Outcomes

Deep-sea corals and sponges are the basis of valuable deepwater ecosystems in the U.S. Southeast, Gulf of Mexico, and Caribbean, and have been identified as important conservation targets in the region. The Deep Sea Coral Research and Technology Program works closely with regional fishery management councils, sanctuaries, and other management agencies to provide conservation-relevant information on these ecosystems.

Research, exploration, and data analysis conducted as part of SEDCI have already begun to inform council and sanctuary management decisions across the greater Southeast U.S.

- In 2018, the Gulf of Mexico Fishery Management Council approved 21 new Habitat Areas of Particular Concern. Thirteen of these areas, covering 304 mi^2, include regulations to protect deep-sea corals from damaging fishing gear. Boundaries were largely informed by DSCRTP-sponsored data collection. These HAPCs are the first coral habitat protections deeper than 200 m in the Gulf, and one of the most enduring outcomes of the initiative.
- The Flower Garden Bank National Marine Sanctuary expanded the Sanctuary by approximately 104 mi^2, adding 14 reefs and banks to the previous three bank system. SEDCI research supported this effort by conducting ROV surveys within and outside the proposed expansion areas, providing example imagery of the areas proposed for expansion, examining coral density, and documenting marine debris at many sites. Sanctuary expansion took effect on March 22, 2021.
- Also, in the Gulf of Mexico, fishery managers used DSCRTP data to exclude known and predicted deep-sea coral locations from newly permitted golden crab harvest areas off the west coast of Florida.
- Both the Gulf of Mexico and South Atlantic Fishery Management Councils are considering additional Deepwater Coral fishery management plan amendments that will use new information collected under SEDCI.
- Extensive new deep-sea coral and sponge observations and production of the first regional habitat suitability models (that identify likely and potential locations of deep-sea corals) will aid the Caribbean Fishery Management Council in upcoming decision-making.

2.3 SEDCI Partnerships

The success of NOAA's Deep Sea Coral Research and Technology Program's Initiatives depends on partnerships. In the Southeast, SEDCI fostered a wide range of partnerships that were essential to success. In addition to fully-funded fieldwork and small projects, SEDCI also supported expeditions and projects by providing staff or forming partnerships. This practice allowed SEDCI to involve more organizations while contributing to the goals of their projects.

OER was an essential partner, especially under the auspices of the ASPIRE (Atlantic Seafloor Partnership for Integrated Research and Exploration) campaign. OER partnered with SEDCI to conduct multiple expeditions aboard NOAA Ship *Okeanos Explorer* that leveraged mutually beneficial objectives for both partners. SEDCI compiled detailed video annotations of corals and sponges from each expedition, and developed a deep-sea coral species identification guide (Salgado & Etnoyer, 2020). SEDCI also participated in DEEP SEARCH, an interagency National Ocean Partnership Program campaign off Georgia and the Carolinas led by BOEM, USGS, and NOAA OER.

In the Gulf of Mexico, SEDCI partnered with NOAA's activities made possible by the RESTORE Act to support ROV sampling for the project '*Population Connectivity of Deepwater Corals in the Northern Gulf of Mexico*.'

Scientists and students from many academic institutions participated at sea, in the labs, and in analyses. These institutions included Florida A&M, Florida State University, Florida Atlantic Univ., Harbor Branch Oceanographic Institution, Nova Southeastern, Mississippi State Univ., Univ. of Texas, Texas A&M, and Woods Hole Oceanographic Institution, among others.

2.4 Student Engagement and Outreach

Student participation in scientific projects, and aboard research cruises, was an important component of the Initiative (see Sec. 6.1). SEDCI assisted in the support of 45 students from high school to PhD students from over 20 institutions. To date, six Masters projects resulted from SEDCI support and two Hollings Scholars completed projects that were mentored by SEDCI scientists. In addition to student projects and participation in research cruises, SEDCI contributed to a two-day deep-sea coral taxonomy and morphology workshop held in conjunction with the NOAA Center for Coastal and Marine Ecosystems meeting in Charleston.

SEDCI led numerous outreach activities and events targeted to the general public, students, and the deep-sea science and management communities (see Section 6.2). Ralf Mayer of Green Fire Productions created an outreach video, Living in the Dark, documenting research during SEDCI cruise NF-17-08 in the Gulf of Mexico. This can be found on the NOAA institutional repository.

3. Fieldwork

3.1 Overview

3.1.1 SEDCI Expedition Inventory

SEDCI contributed to 21 research expeditions from 2016-2019 by providing funding or scientific staff (Table 1). Expeditions occurred in all three SEDCI regions (Figure 1) and included video and images from autonomous underwater vehicle (AUV), ROV, and human occupied vehicle (HOV) dives, seafloor mapping, retrieval of a coral lander, water samples for environmental DNA studies, live coral samples, geological samples, and deep-sea larval studies, among other activities.

One of the most remarkable aspects of SEDCI was the diversity of platforms used to achieve an unprecedented level of exploration, over a broad extent, across the four-year project timeframe. SEDCI logged more than 250 days at sea using a broad portfolio of research vessels working in different regions under the guidance of different principal investigators. A variety of vehicle types was employed. SEDCI used ROVs, AUVs, and manned submersibles to explore the seafloor, thanks to our partnerships with NOAA OER, BOEM, USGS, the DEEP SEARCH campaign, and the Office of National Marine Sanctuaries, particularly Flower Garden Banks and Florida Keys.

The most productive vessels, strictly in terms of the number of dives, were the R/V *Manta* (137 ROV dives over six expeditions with the University of North Carolina Wilmington's (UNCW) ROV *Mohawk*) and NOAA Ship *Okeanos Explorer* (99 ROV dives over six expeditions with ROV *Deep Discoverer*). ROV *Mohawk*, reaching a maximum depth of 245 m, conducted multiple dives a day. In contrast, ROV *Deep Discoverer,* capable of exploring depths between 250-6,000 m, was limited to one dive per day. Two other vessels logged more than 40 dives. NOAA Ship *Nancy Foster* had 71 dives over five expeditions with ROV *Odysseus* off West Florida, and with ROV *Mohawk* in the U.S. Virgin Islands and Puerto Rico. NOAA Ship *Pisces* contributed substantially as well, with three cruises producing 10 AUV dives with *Sentry*, and 29 dives with ROV *Mohawk*. The intrepid R/V *Atlantis* had one cruise with 12 dives by HOV *Alvin* in 2018, with a maximum depth of 2,169 m. This cruise and the *Pisces* cruises had only supplementary support from SEDCI. These operations were led by NOAA Fisheries' Office of Science and Technology and BOEM, respectively, with support in both cases from NOAA OER.

Table 1. Research expeditions supported by SEDCI from 2016-2019.

SurveyID	Lead (s)	Start date	End date	# of Dives	Region	Depth (m)	# of Samples	km² mapped
PC1605	Martha Nizinski	8/24/2016	9/4/2016	3 (AUV)	SEUS	700-1900	NA	NA
DFH 30	Emma Hickerson	9/4/2016	9/8/2016	28	GoMx	61-192	24 Biological	NA
NF1708L1	Peter Etnoyer	8/12/2017	8/24/2017	13	GoMx	310-780	50 Biological, 3 Geological	2,272
NF1708L2	Daniel Wagner	8/27/2017	8/31/2017	NA	SEUS	NA	NA	480
PC1704	Martha Nizinski	8/28/2017	9/8/2017	7 (AUV)	SEUS	900-2000	NA	29
DFH 32	Emma Hickerson	9/21/2017	9/26/2017	32	GoMx	37-211	55 Biological, 2 Geological	NA
DFH 33	Emma Hickerson	9/28/2017	10/1/2017	17	GoMx	66-147	38 Biological	NA
EX1711	Chuck Messing (NSU), Diva Amon (NHMUK)	11/29/2017	12/21/2017	17	GoMx	300-2324	105 Biological, 9 Geological	26,000
EX1803	Adam Skarke (MSU), Daniel Wagner	4/11/2018	5/3/2018	15	GoMx	305-3010	67 Biological, 12 Geological	21,100
PC1802	Stacey Harter, John Reed (HBOI)	5/12/2018	5/24/2018	29	SEUS	45-267	22 Biological	131
EX1806	Cheryl Morrison (USGS), Leslie Sautter (CofC)	6/13/2018	7/2/2018	17	SEUS	450-3470	175 Biological, 38 Geological	13,608
NF1804	Tim Battista	6/25/2018	7/7/2018	27	Caribbean	40-300	NA	350
DFH35	Emma Hickerson	7/21/2018	7/26/2018	14	GoMx	60-160	23 Biological	NA
AT-41	Erik Cordes (TU)	8/19/2018	9/2/2018	11 (HOV)	SEUS	404-1948	571 Biological, 170 Geological	NA
DFH37	Emma Hickerson	9/6/2018	9/10/2018	21	GoMx	60-143	68 Biological	NA
RESTORE 2	Santiago Herrera (LU)	9/16/2018	9/23/2018	26	GoMx	40-120	265 Biological	NA
EX1811	Steve Auscavitch (TU), Stacey Williams (ISER)	10/30/2018	11/20/2018	19	Caribbean	250-5000	81 Biological, 8 Geological	14,429
EX1903L2	Amy Wagener, Alexis Weinnig (TU)	5/30/2019	7/12/2019	19	SEUS	293-3490	166 Biological, 12 Geological	28,988
NF1901	Tim Battista	6/30/2019	7/12/2019	31	Caribbean	20-290	41 Biological	461
NF1909	Jay Lunden (TU)	10/22/2019	10/30/2019	NA	SEUS	NA	NA	NA
EX1907	Stephanie Farrington (HBOI), Kimberly Galvez (Univ of Miami)	10/31/2019	11/20/2019	12	SEUS	347-1218	69 Biological, 6 Geological	33,000

3.1.2 SEDCI Dive Locations

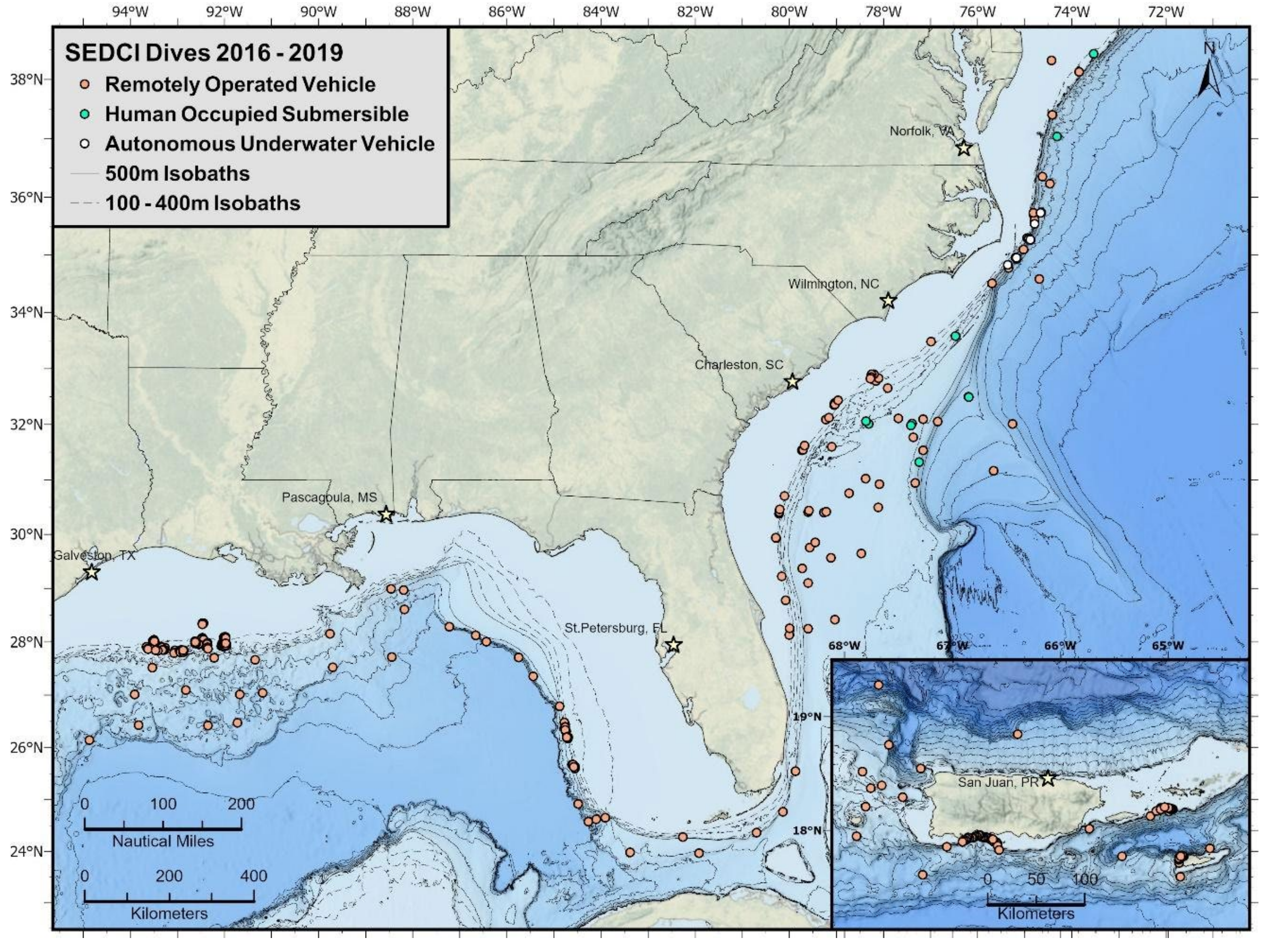

Figure 1. Locations of SEDCI dives in all three regions from 2016-2019, including ROV, HOV, and AUV dives.

3.1.3 SEDCI Sample Collections

Of the 21 cruises that received funding or personnel from SEDCI, 16 of them collected samples. In total, 1,820 biological samples and 260 geological specimens were collected. The method of collection was mainly manipulator arm or suction sampler from an ROV but there were also samples collected with an HOV via core sampling, manipulator arm and slurp sampler.

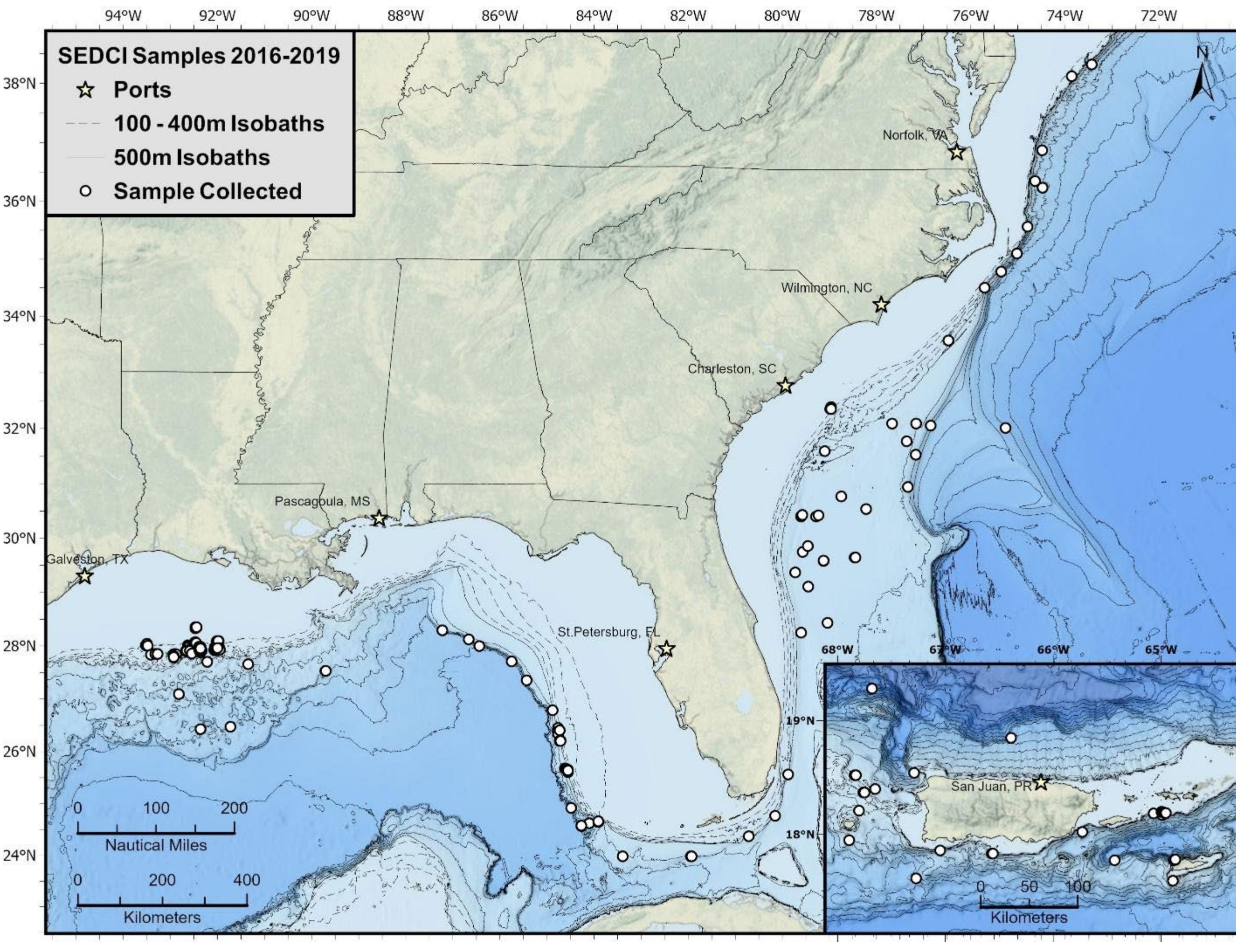

Figure 2. Locations of SEDCI sample collection locations in all three regions from 2016-2019.

3.1.4 SEDCI Fieldwork Partners

SEDCI aimed to build and maintain a broad portfolio of field projects and partners. In order to do this, the Initiative engaged in a variety of funding arrangements that ranged from full-funding, to partial funding, and supplemental funding. Most field projects received partial funding. These amounts ranged from $75- 150K over the course of one year or more, and contributed substantially to partnerships. Supplemental funding arrangements contributed modest amounts (< $50K) to support staffing, travel, supplies, and equipment.

Three key partners were NOAA OER and the expeditions of NOAA Ship *Okeanos Explorer*; the interagency DEEP SEARCH collaboration with NOAA, BOEM, and USGS; and NOAA's activities made possible by the RESTORE Act.

NOAA Ocean Exploration:

NOAA OER is the only U.S. federal program dedicated to exploring our deep ocean. Through live video streams, online coverage, training opportunities, and real-time events, OER allows scientists, resource managers, students, members of the general public to actively experience ocean exploration. NOAA Ship *Okeanos Explorer* is the only U.S. federal vessel dedicated to exploring our largely unknown ocean for the purpose of discovery and the advancement of knowledge. Working in close collaboration with government agencies, academic institutions, and other partners, OER conducts deep-sea exploration expeditions using advanced technologies on NOAA Ship *Okeanos Explorer*.

Under the auspices of the ASPIRE campaign, NOAA OER partnered with SEDCI to conduct multiple expeditions that leveraged mutually beneficial objectives for both partners. SEDCI provided partial funding and staff support for all NOAA Ship *Okeanos Explorer* expeditions in the Southeast U.S. and Caribbean region from 2017-2019. SEDCI research coordinator Daniel Wagner served as lead scientist aboard EX1803. A "pop-up" Exploration Command Center (ECC) was established at Hollings Marine Laboratory in Charleston, South Carolina to live stream the expeditions and advise exploration activity. Drop-in "watch parties" were hosted in this ECC during two of the *Okeanos Explorer* cruises, during which the public was invited to come and watch the dives in real time. NOAA Deep Coral Ecology Lab and OER staff were there to give a tour of the ECC and an overview of the exploration process and technology used by NOAA Ship *Okeanos Explorer*. SEDCI partners at NCCOS also represented OER by hosting live viewings of NOAA Ship *Okeanos Explorer* dives at the South Carolina Aquarium.

Detailed video annotations were compiled for each expedition, including expert identification of the organisms observed in much of the ROV video collected during the dives. These annotations were made public through NOAA's National Database of Deep Sea Corals and Sponges, and Ocean Networks Canada's SeaTube platform. Species IDs were made public through a photo catalog in the form of a peer-reviewed species identification guide (Salgado & Etnoyer, 2020)

References and document links:

Salgado EJ and Etnoyer PJ (2020). Photographic catalog of deep-sea corals collected from the US West Atlantic margin by NOAA Ship *Okeanos Explorer* in years 2017- 2019. NOS NCCOS 273. 132 pp. repository.library.noaa.gov/view/noaa/25517

Deep Sea Exploration to Advance Research on Coral/Canyon/Cold Seep:

DEEP SEARCH is an interagency partnership campaign led by BOEM, USGS, and NOAA OER through 2017-2019. The mission of DEEP SEARCH (Deep Sea Exploration to Advance Research on Coral/Canyon/Cold seep Habitats) is to explore and characterize sensitive deep-sea habitats—submarine canyons, methane seeps, and deep-sea coral communities—in the U.S. South and Mid-Atlantic. The project was sponsored by the National Oceanographic Partnership Program, and managed by TDI Brooks International. The participants included principal investigators from six U.S. academic institutions, one international academic institution, and five USGS science centers.

The project study area encompassed the majority of the BOEM Mid-Atlantic and South Atlantic Outer Continental Shelf planning areas, spanning deepwater offshore areas from Virginia to Georgia. With such a large study area, the field research program was designed to be comprehensive, using multiple platforms and technologies. In 2017, NOAA Ship *Pisces* deployed AUV *Sentry* in the area to generate initial maps of potential study sites. In 2018, OER executed missions on NOAA Ship *Okeanos Explorer* adding significant multibeam bathymetry coverage in the study area, which was then used to plan an R/V *Atlantis* expedition with HOV *Alvin* and site the deployment of two benthic landers from R/V *Brooks McCall*. SEDCI contributed staff time and partial funding to the R/V *Atlantis* mission, which explored the Richardson Reef area and was led by Erik Cordes of Temple University.

In 2019, DEEP SEARCH completed its final and most intensive field season, with a spring expedition on NOAA Ship *Ronald H. Brown* with ROV *Jason* and a fall expedition on NOAA Ship

Nancy Foster. Both expeditions returned to sites identified by the earlier missions and significantly expanded our knowledge of the U.S. southeastern continental margin. The DEEP SEARCH team will continue analyzing data collected from these expeditions until the project concludes with a final, comprehensive report in 2022.

NOAA's Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies (RESTORE):

SEDCI contributed supplemental funds to a partnership with activities made possible by the RESTORE Act in the Gulf of Mexico (Lead PI – Herrera), with the Coral Reef Conservation Program in the Southeast U.S. (Lead PI – Harter) and Caribbean (Lead PI – Battista), and with NOAA Fisheries in Puerto Rico (PI – David).

The partnership with RESTORE supported ROV sampling for the project entitled 'Population Connectivity of Deepwater Corals in the Northern Gulf of Mexico. A total of $40K was contributed by SEDCI to lease UNCW's ROV *Mohawk* in year 2018. This project focused on four species of mesophotic and deepwater octocorals that were injured by the Deepwater Horizon (DWH) oil spill. The project sought to address crucial gaps in the understanding of the processes that influence population connectivity patterns of deepwater and mesophotic corals, in order to aid management decisions. The research team combined field sampling, population genomic analyses, and physical oceanographic modeling to define spatial scales of coral populations, infer directionality and rates of genetic exchange, and integrate predictive models of larval dispersal with genetic data to estimate dispersal distances and patterns. The information gained from the project is intended to aid decision-making by the Gulf of Mexico Fishery Management Council and support ongoing development of marine protected areas for deepwater corals.

3.2 SEDCI Fieldwork in the Gulf of Mexico

SEDCI fieldwork addressed pressing management priorities relating to deepwater corals in the Gulf of Mexico: (1) inform proposed FGBNMS boundary changes, (2) inform the Gulf of Mexico FMC's delineation and deliberation regarding newly proposed deepwater HAPCs, and (3) create models that can be ground-truthed to predict possible coral habitat in unsurveyed areas.

Images, maps, graphs, other key figures:

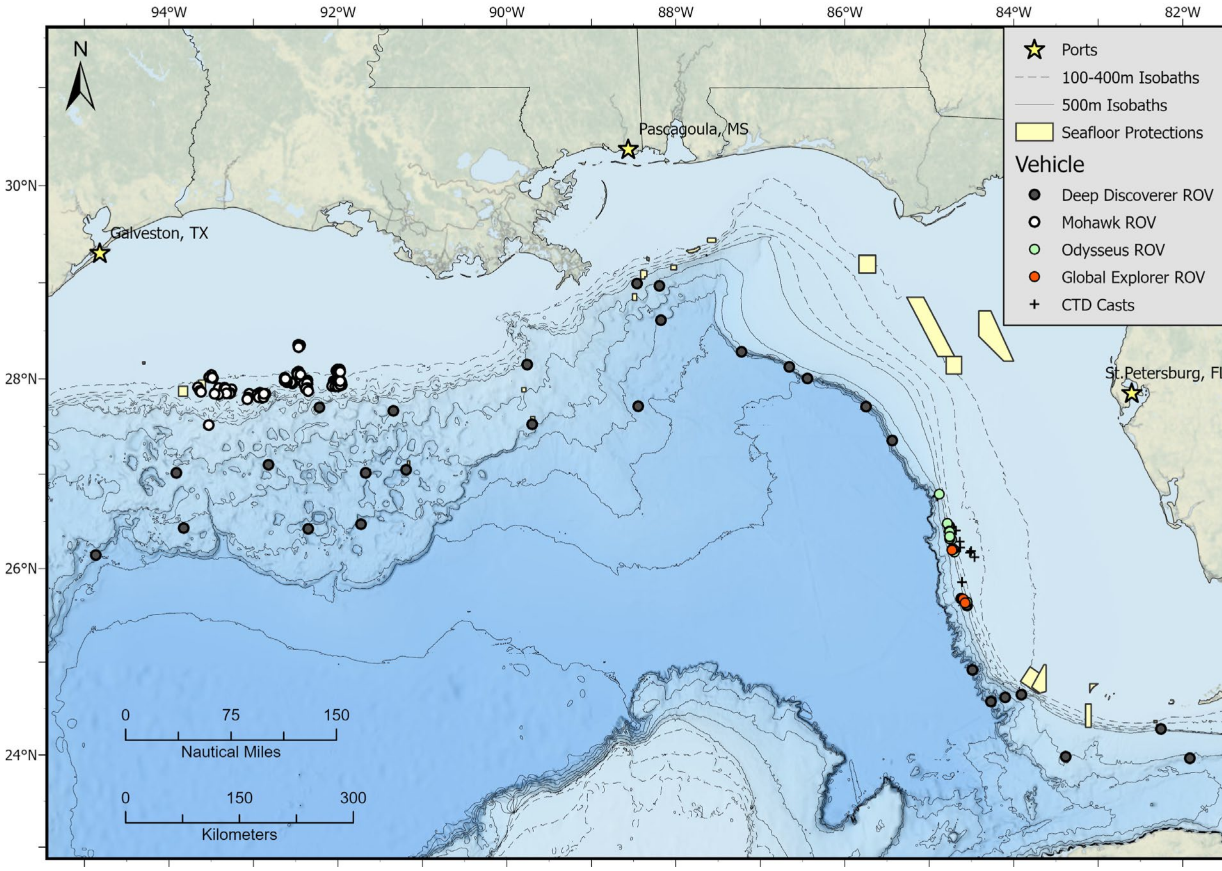

Figure 3. Locations of SEDCI dives and CTD casts performed in the Gulf of Mexico from 2016-2019.

3.2.1 Site Characterization of Reefs and Banks in the Northwestern Gulf of Mexico to Inform Proposed Boundary Changes for the Flower Garden Banks National Marine Sanctuary

Background and Objectives:

FGBNMS was designated a nationally significant marine feature in 1992, under the National Marine Sanctuaries Act (56 FR 63634), and consisted of two underwater features: East and West Flower Garden banks, then Stetson Bank was added in 1996 (Pub. L. 104-283). FGBNMS has a long-standing monitoring program that investigates temporal and spatial trends in the benthic and fish communities and water quality parameters, on the coral caps of the three banks. In the 1970s, interest in reefs and banks located outside of the current boundaries began, while more focused investigations to characterize these areas were renewed in the early 2000s. Since 2001, FGBNMS has been investigating the northwestern Gulf of Mexico (NWGoM) and now possesses the most extensive records of mesophotic coral ecosystems that exist in the region. In 2016, FGBNMS collaborated with the Deep Sea Coral Research and Technology Program to gather environmental data and geo-referenced points of benthic habitat and biology to generate habitat characterization maps and predictive habitat models for reefs and banks in the NWGoM. This collaborative effort supported the exploration and characterization of nationally significant corals and sponges on reefs and banks that were included in the proposed boundary expansion of FGBNMS (Figure 4; ONMS 2020). Through DSCRTP, it also provided data, images, and technical reports in a readily accessible online portal in support of the program's initiatives.

Since 2001, over 25,000 still images were collected by FGBNMS, which were critical for the efforts to propose the expansion of the current Sanctuary boundaries. FGBNMS collaboration with the DSCRTP extended these historical data and applied them by developing habitat characterization maps of the surveyed banks, exploring, and characterizing additional areas of these underwater features. In addition, these data were incorporated into the DSCRTP database, adding valuable quantitative habitat and coral records that were useful for improving their understanding of the benthic habitats and populations within the NWGoM region.

This report briefly summarizes the significant results from three years, 2016-2018, of research expeditions that explored deep-sea habitats in the NWGoM. ROV *Mohawk* was deployed from NOAA's R/V *Manta* to survey reefs and banks with three primary objectives: (1) conduct analyses of habitat, coral, sponge and fish density using imagery and video collected from: Alderdice, Bouma, Bright Complex, Bryant, East Flower Garden (EFGB), Geyer, MacNeil, McGrail, Parker, Rezak, Sidner, Sonnier, and Tresslar banks; (2) generate habitat maps that accurately represent the environments found on the seafloor; and (3) contribute density and species data into the DSCRTP data portal. In addition, a final primary objective of this collaboration was to (4) conduct habitat data analysis of historic photographic transects collected at Horseshoe, MacNeil, Rankin, 28 Fathom, Bright, Geyer, Elvers, McGrail, Sonnier, Bouma, Bryant, Rezak, Sidner, Alderdice, and Parker banks. Each expedition sought to accomplish these primary objectives by: (1) capturing video and imagery surveys of deep-sea coral ecosystems; (2) confirming model predictions of mesophotic habitats; (3) exploring previously unsurveyed sites; (4) collecting biological specimens of mesophotic corals, sponges, and associated taxa for confirmation of identifications; and (5) ground-truthing predictive habitat models and habitat maps for the reefs and banks in the proposed expansion for FGBNMS.

Approach:

ROV surveys were conducted aboard the R/V *Manta*, an 82-foot catamaran used as a research platform in the NWGoM. UNC Wilmington's Underwater Vehicles Program was essential to the effort. During the expeditions, ROV seafloor surveys and transects were completed and samples of mesophotic organisms were taken. For each cruise, a minimum of three drop sites at each bank were pre-planned based on high resolution multi-beam bathymetry. A minimum of one transect was conducted during each dive. Annotations were collected throughout the entirety of each dive and treated as separate records to document time, location, events, fish and benthic biological occurrence with relative abundance, habitat type, and items of note. Time codes were used to consociate dive tracks, annotations, high definition video, standard definition (SD) video, still images, and frame grabs. Short, five-minute benthic and fish transects that corresponded to approximately 100 m were conducted over a variety of hard and soft bottom habitats.

Five expeditions were completed – one in 2016 (DFH30), two in 2017 (DFH32 and DFH33), and two in 2018 (DFH35 and DFH37), respectively. In several instances, reefs and banks were visited in consecutive years to allow for a more robust dataset and to explore additional areas in the underwater system. In total, mesophotic and shallow habitats (depth range 26 – 186 m) from fourteen banks were surveyed during this project: Alderdice, Bouma, Bright Bank Complex (comprised of Bright, 28-Fathom, and Rankin banks), Bryant, East Flower Garden, Elvers, Geyer, MacNeil, McGrail, Parker, Rezak, Sidner, Sonnier, and Tresslar banks. One hundred eleven ROV dives were completed, in which 218 one-hundred-meter benthic transects, covering 32,700 m^2 and comprising approximately 108 hours of bottom time, were achieved. Additionally, 217 biological specimens were collected for identification through genetic and/or morphological analyses by external partners at the City University of New York (CUNY), University of Texas Rio Grande Valley (UTRGV), UNCW, University of Louisiana at Lafayette, and NOAA NCCOS's Beaufort lab.

Coral and sponge data were quantified using still camera imagery captured during ROV transects, while fish data were quantified using high-resolution video. Habitat was predicted using the maximum entropy (Maxent) estimation method, developed for modeling species geographic distributions (Elith et al., 2010; Phillips et al., 2006; Phillips and Dudik, 2008; Sterne, 2018). This type of model was most appropriate for this project, as it predicted a probability of occurrence of each habitat type across the full extent of the bank areas consistent with covariate values (depth, bottom slope, slope of slope, rugosity, plan curvature, and aspect) observed. As a final output, a predictive habitat map was generated in ESRI's ArcMap that represented the distribution of habitats across each bank. DSCRTP ROV transects were overlain on the model with colony count point data to determine the percentage of habitats that were correctly predicted.

Significant results to date:

Relevance to Flower Garden Banks Expansion
FGBNMS recently expanded boundaries by approximately 104 mi^2 with the release of the Final Rule (86 FR 4937) and added 14 reefs and banks to the previous three bank system. DSCRTP cruises supported many of these efforts by providing example imagery of the areas proposed for expansion, examining coral density, and documenting marine debris at many sites. From 2016-2018, 25% of the DSCRTP ROV transects were conducted within the boundaries of NOAA's Final Preferred Alternative (Figure 5). ROV transects conducted outside of the Final Preferred Alternative boundaries are important for other regulatory efforts, specifically BOEM's reassessment of biological stipulations, and the Gulf of Mexico Fishery Management Council's management of Essential Fish Habitats.

Identification of new species and range expansions
During the DSCRTP expeditions in the NWGoM, two new species of deepwater black coral were discovered, one being *Distichopathes hickersonae* (Figure 6; Opresko et al., 2020). A second potential new species of black coral, belonging to the family Stylopathidae, was collected and is awaiting confirmation by partners at Mercer Brugler's lab at University of South Carolina-Beaufort. In 2018, researchers observed a Maori basslet (*Lipogramma schrieri*) for the first time in the NWGoM, at Geyer Bank, documenting a range extension of this cryptic species (Figure 7). Baldwin et al., (2018) only recently described this species in 2018 during submersible dives off Curaçao in the southern Caribbean at 197 m depth.

Densities of Mesophotic and Deepwater Corals
Mean coral density, reported by species and averaged across each bank, surveyed during DSCRTP cruises, ranged from 0.31 – 3.25 colonies m^2 (ind m^2), but was as high as 7.39 (*Antipathes furcata*) and 35.47 colonies m^2 (juvenile *Madracis brueggemanni*). These coral density values are relatively high compared to some other surveys at similar depths reported from the Gulf of Mexico (e.g., Etnoyer et al., 2016), and well above the threshold of one colony per 100 sq m often used to define "coral garden" habitat (e.g., ICES, 2007, Bullimore et al., 2013). This signifies that the bank habitats in the northwest Gulf of Mexico (NWGoM) contain relatively high densities of deepwater corals.

Significance of Soft Bottom Habitat for Deepwater Coral Ecosystems

This initiative offered important information that previous research has not investigated (e.g., Sammarco et al., 2016), by examining the density and occurrence of the benthic coral communities in soft bottom habitats, as well as the hard bottom habitats. A cluster analysis revealed that soft bottom communities were very similar in coral species composition to deep coral and coralline algae habitats, a phenomenon that has not been documented previously (Figure 8). In general, corals broadly appeared to have lower occurrence in soft bottom when compared to coralline algae and deep coral habitats. The prominent species observed in soft bottom across all banks were *Nicella* sp., *Stichopathes* sp., and *Elatopathes abietina*. The occurrence of coral in soft bottom communities and heavily sedimented areas may be a function of their biological abilities, such as attachment potential or mechanism, though that level of interpretation was not attempted with this analysis. Importantly, this study contributed critical information about the density and diversity of corals in soft bottom communities and heavily sedimented areas that were otherwise believed to lack such fauna. It is clear these areas support more diverse biological assemblages than previously known, and warrant further work to evaluate ecological roles, threats, and potentially, needs for protection.

Predictive Habitat Models

Predictive Habitat Models (PHM) were developed as part of this initiative, in which Sonnier Bank presented the most diverse distribution of habitat types of all of the banks (Figure 9). In all cases, soft bottom habitat and transitional zones were predicted to be predominant, typically comprising >50% of the overall coverage. Approximately 29% (n = 4) of the PHMs did not reliably predict habitat coverage that was observed on DSCRTP benthic surveys. Overall, the PHMs correctly predicted as low as 0% (i.e., Bouma and Sidner banks) of habitat observed on DSCRTP cruises, but as high as 78% (i.e., Sonnier Bank), with a mean 31% ± 6% standard deviation. The habitat maps developed from this effort are an extremely useful tool for future research and management purposes and will be integrated into the Sanctuary's mapping tool, while the data collected during field operations were an effective way to test the accuracy of the models. The model did not represent hard bottom habitats such as algal nodules/reefs well, likely attributed to the lack of hardness measures, such as an acoustic backscatter. Incorporating this as a covariate in the model would have added a valuable component to improve the accuracy of prediction. It will be advantageous for future habitat models to include a hardness measure, and for acoustic backscatter to be a regular component of multi-beam mapping of benthic habitats.

Conclusion:

Nearly all of the banks described in this study were explored prior to the DSCRTP cruises, by FGBNMS or affiliates, and recommendations were provided to classify these features as top priorities for environmental protection (e.g., Rezak et al., 1985; Sammarco et al., 2016). The DSCRTP efforts further supported these recommendations by providing the discovery of new species and range extensions of others, coral density measures, predictive habitat models, information on the occurrence of benthic communities on soft-bottom and hard-bottom habitats, and characterization of reefs and banks included in the expansion of FGBNMS (86 FR 15404). FGBNMS is currently updating their Sanctuary Condition Report and will use information gathered during these DSCRTP cruises to provide baseline data for the mesophotic reefs and banks added with the expansion. The reefs and banks described in this report are an ecological network of marine communities interconnected physically and ecologically. They offer continuity of habitat for marine organisms, may act as "habitat highways" for migratory species, and provide suitable substrate for the colonization and development of benthic communities (Schmahl et al., 2008). As such, these ecosystems warrant additional characterization of the benthos and fish communities to ensure the most comprehensive descriptions of these distinctive ecosystems are available to guide resource management. This initiative supports decades of research that has identified significant natural features throughout the NWGoM and continues to highlight the need for dedicated management and protection of these underwater treasures.

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Images, maps, graphs, other key figures:

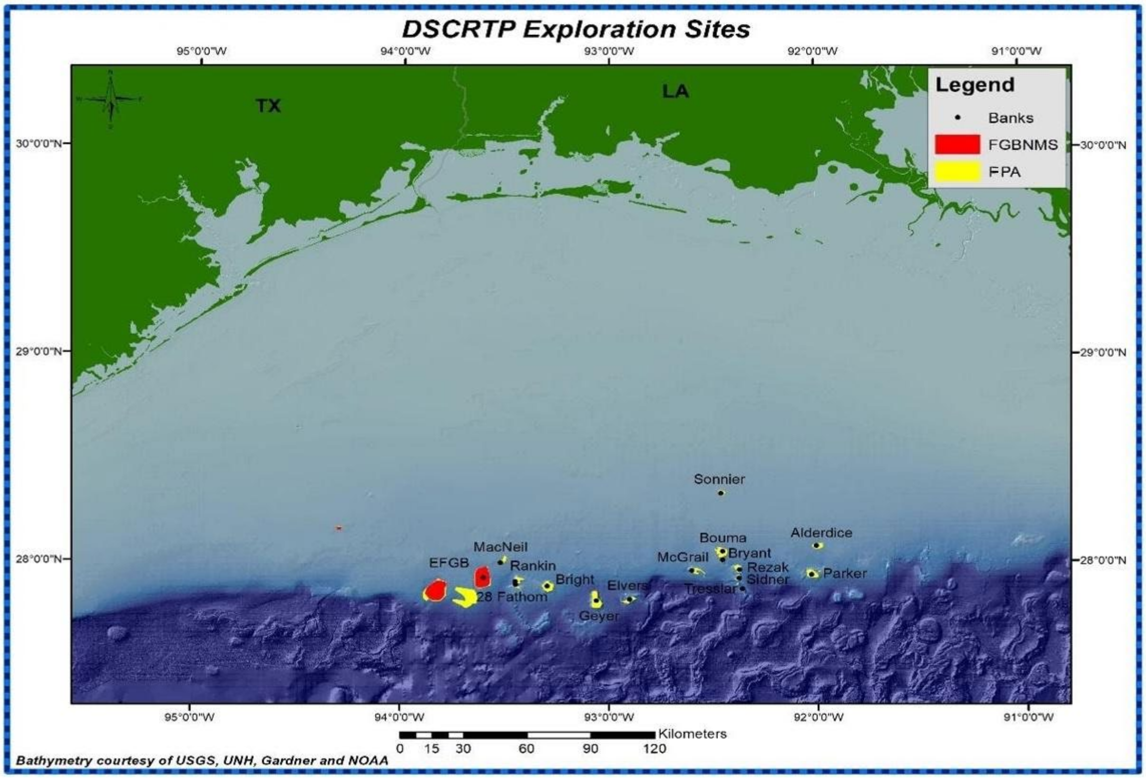


Figure 4. Overview map of reefs and banks explored during DSCRTP cruises 2016-2018. The FGBNMS boundaries prior to expansion are represented in red, while the yellow polygons signify the area proposed for expansion as the Final Preferred Alternative (FPA) in the NOAA's Final Environmental Impact Statement (ONMS 2020).

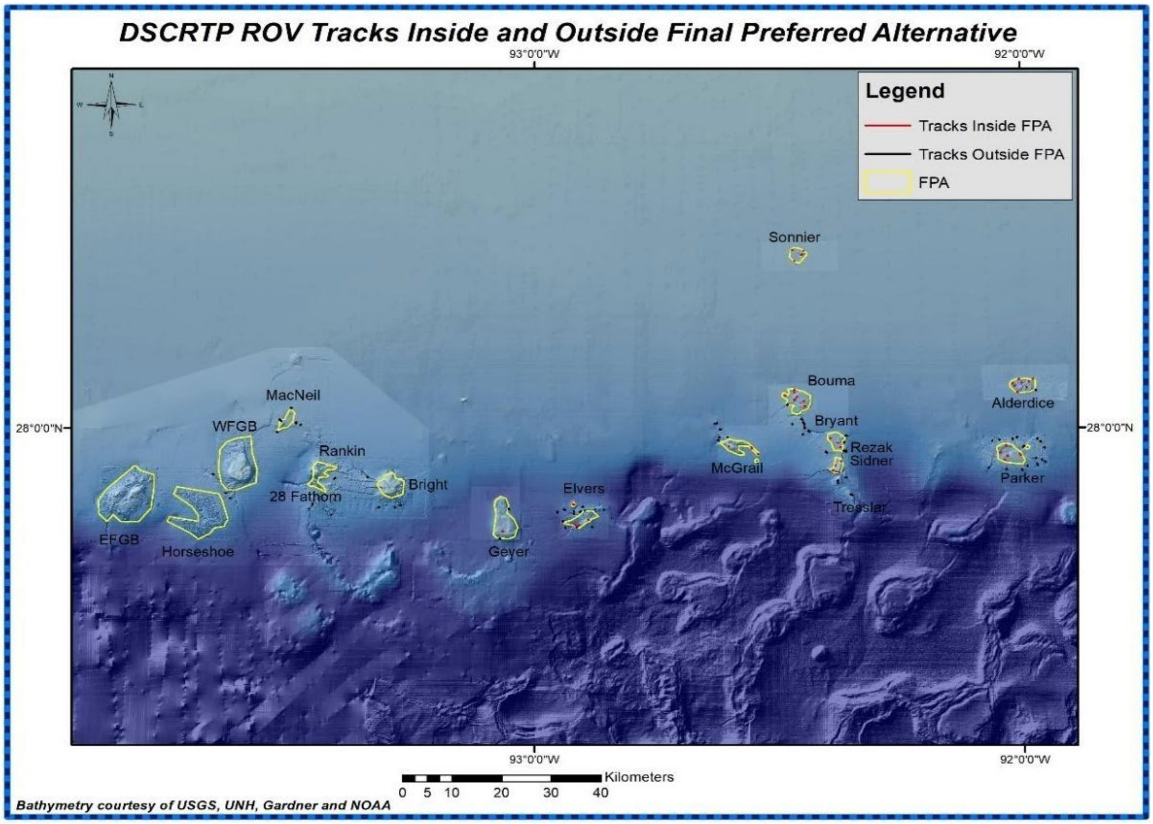


Figure 5. DSCRTP ROV tracks conducted within the boundaries of the Final Preferred Alternative (FPA) are shown in red, while ROV tracks that explored areas outside of the FPA are presented in black. NOAA's FPA boundaries, as presented in the FEIS (ONMS 2020), are shown in yellow.

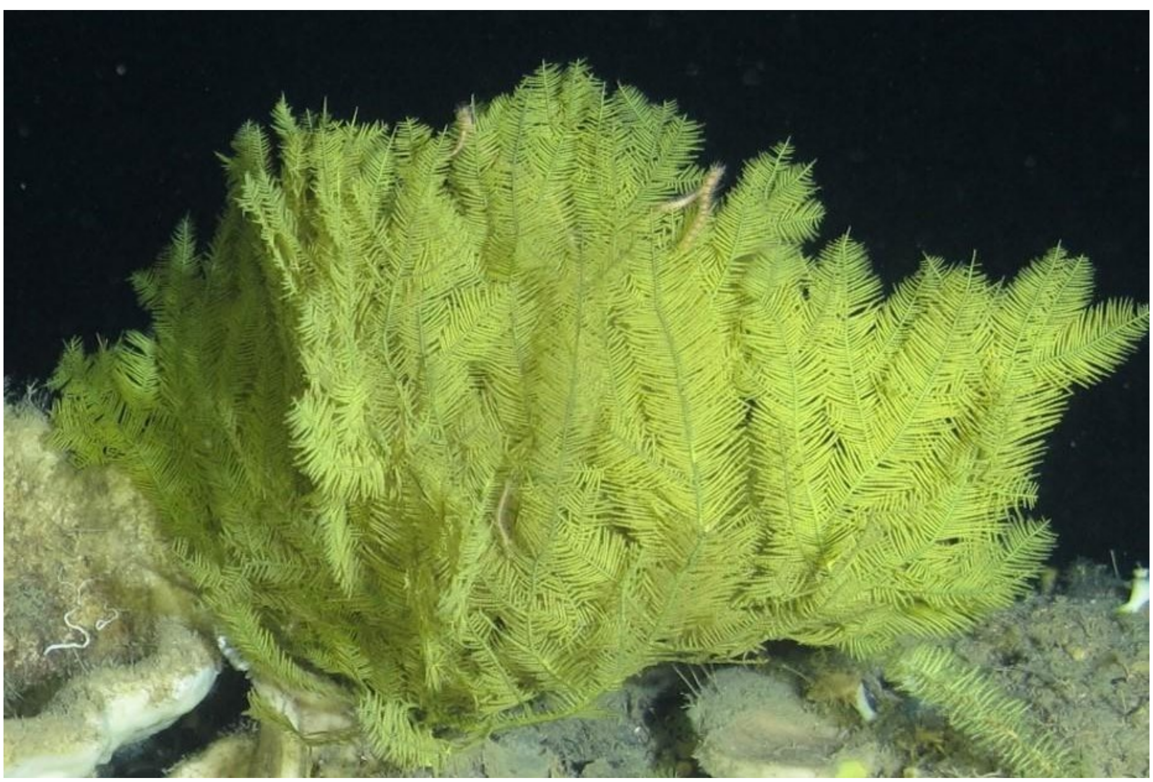


Figure 6. New species of black coral, *Distichopathes hickersonae*, observed on an eroded outcrop at Elvers Bank in 2016 (DFH30) amongst large cup sponges at 172 m depth. Photo: NOAA/UNCW-Undersea Vehicle Program.

Figure 7. First documented sighting of a Maori basslet (*Lipogramma schrieri*) in deep coral habitat in the NWGoM – 2018 SEDCI cruise at 141 m depth at Geyer Bank. Photo: NOAA/UNCW-Undersea Vehicle Program.

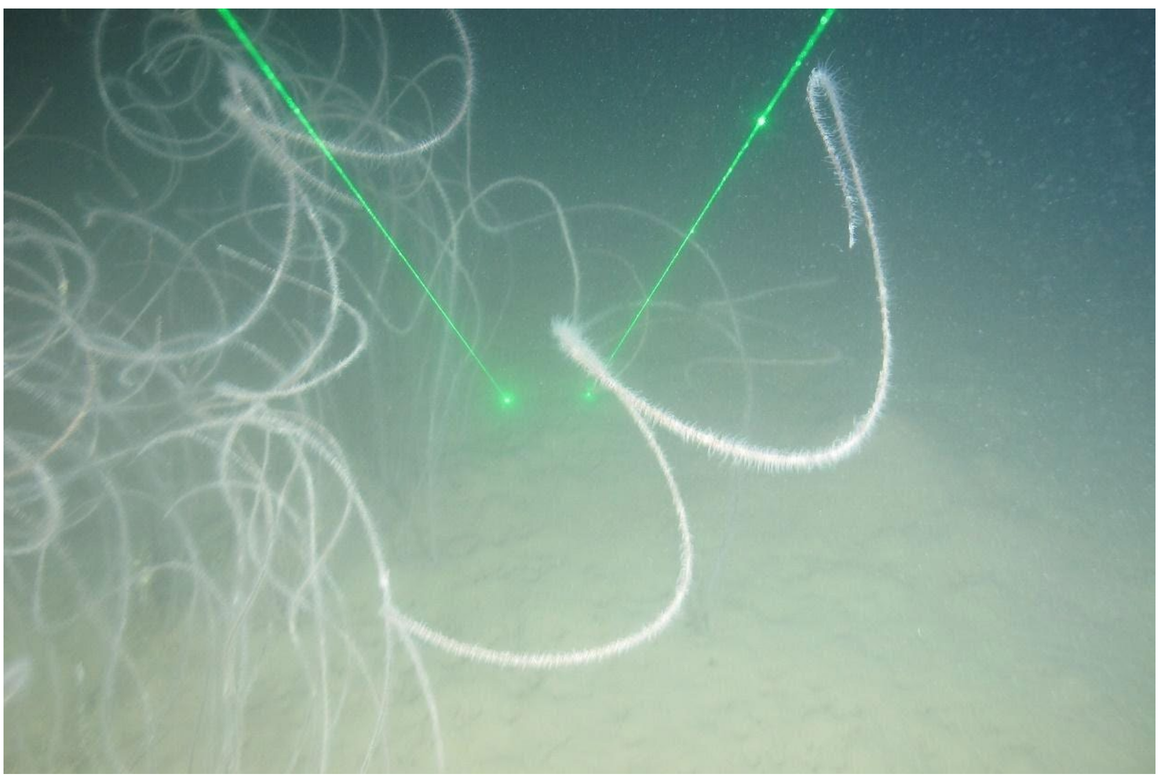


Figure 8. Soft bottom habitat with dense clusters of sea whips observed at Alderdice Bank in 2018 (DFH37) at 89 m depth. Photo: NOAA/UNCW-Undersea Vehicle Program.

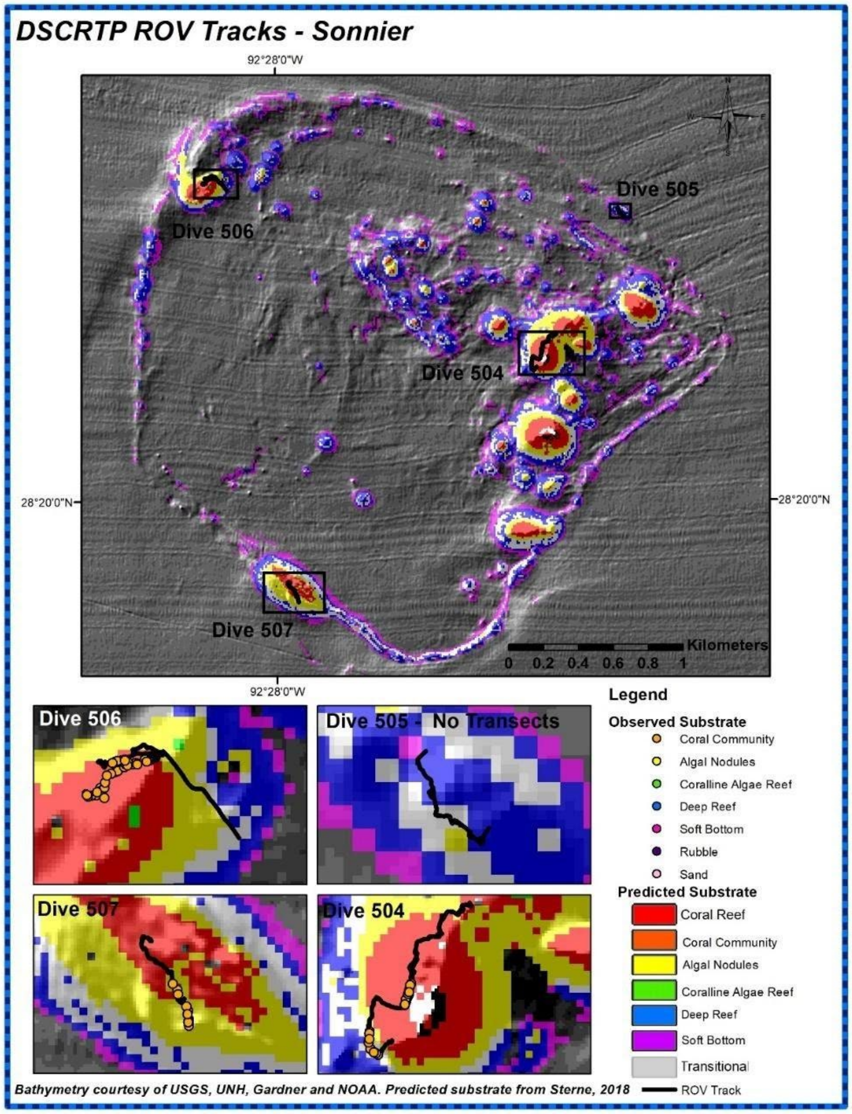


Figure 9. Sonnier Bank habitat map that provides predicted habitats at the top generated from predictive habitat modelling (Sterne, 2018), and DSCRTP ROV track lines indicated with their respective dive number. The inset maps provide the habitat coverage described from coral colony count data gathered from the DSCRTP ROV transect surveys. The inset maps include transect data from dives 504, 506-507 (DFH32, 2017). Image: NOAA.

3.2.2 NOAA Ship *Okeanos Explorer* Expeditions in the Gulf of Mexico

Background and Objectives:

In 2017 and 2018, there were two major ROV expeditions conducted by NOAA OER in the Gulf of Mexico that contributed to SEDCI objectives of documenting deep-sea coral and sponge diversity: EX1711 from November 29, 2017 to December 21, 2017 and EX1803 from April 11 to May 3, 2018. Together, the expeditions aboard NOAA Ship *Nancy Foster* (see 3.2.2) and NOAA Ship *Okeanos Explorer* provided a wealth of new insights to Gulf of Mexico Fishery Management Council. SEDCI provided quantitative annotations of deep-sea corals and sponges encountered on all dives of these expeditions. The new observations and analyses contributed substantially to informing the boundaries of the West Florida Wall HAPC, designated in 2020.

OER conducted telepresence-enabled ocean exploration expeditions on NOAA Ship *Okeanos Explorer* to engage the public in the collection of critical baseline data and information and to improve knowledge about unexplored and poorly understood deepwater areas of the Gulf of Mexico. The goal of both expeditions was to use ROV dives in combination with mapping operations to increase scientific understanding of deep-sea ecosystems in this region, as well as to provide a foundation of publicly accessible data to spur further exploration, research, and management activities.

Specific SEDCI-relevant objectives included the following:

- Acquire data about deepwater habitats in the Gulf of Mexico to support priority science and management needs
- Identify, map, and explore the diversity and distribution of benthic habitats, including fish habitats, deep-sea coral and sponge communities, chemosynthetic communities, and biological communities that colonize or aggregate around shipwrecks
- Investigate biogeographic patterns of deep-sea diversity and connectivity across the Gulf of Mexico for use in broader comparisons of deepwater habitats throughout the basin
- Explore areas relevant to resource managers such as Essential Fish Habitats, HAPCs, National Marine Sanctuaries, and potential expansion areas
- Collect high-resolution bathymetry data in areas with no or low-quality mapping data
- Acquire a foundation of ROV, sonar, and oceanographic data to understand the characteristics of the water column and fauna
- Conduct outreach and education activities to engage the public

Approach:

Using OER's dual-body ROV, *Deep Discover,* 32 ROV dives were conducted over 45 days at sea that ranged in depth from 300 to 3,010 m, and included midwater exploration ranging in depth from 300 to 2,100 m. In total, 224 biological samples and 23 geological samples were collected.

Significant Results to Date:

During the 17 ROV dives of EX1711 (Figure 10) and the 15 ROV dives of EX1803 (Figure 11), hundreds of species of animals were observed, including several potential new species, new records for the region, and several significant range extensions. Several organisms were also seen alive for the first time. Relevant highlights include:

EX1711

- EX1711 ROV Dives 01, 03, 04, 10 and 13 surveyed five HAPCs proposed by the Gulf of Mexico FMC in order to collect critical baseline information to inform science and management needs. Four of these sites, Dives 01, 03, 04 and 10, hosted high-density deep coral and sponge communities and one (Dive 10) had extensive chemosynthetic communities.
- EX1711 ROV Dives 09, 10, 13, 15, 16 and 17 also explored six FGBNMS proposed expansion zones to collect critical baseline information to inform science and management needs. High-diversity and density coral and sponge communities were discovered at two of the areas, including a spectacular *Madrepora oculata*-dominated coral garden. Chemosynthetic communities, including brine rivers, large mussel beds, and asphalt seeps were observed in five of these proposed expansion zones.

EX1803

- Deep-sea coral and sponge communities were documented during 12 of the 15 EX1803 ROV dives (Dives 03-15). Five sites had high-density communities of deep-sea corals, one of which is currently among the deepest known (2,600 m) high- density communities in the Gulf of Mexico.
- EX1803 surveyed two sites identified by the Gulf of Mexico FMC for potential future establishment of HAPCs, and to help provide critical baseline data and information to inform science and management decisions.
- EX1803 explored two proposed expansion areas for FGBNMS.
- Over 42,099 sq km of seafloor were mapped over the course of the two expeditions.
- 167 scientists participated remotely in these expeditions via telepresence technology.

Point of Contact:

Caitlin Adams (caitlin.adams@noaa.gov), NOAA OER

References and document links:

All data collected during the EX1711 and EX1803 expeditions, including video, environmental, mapping, oceanographic, and meteorological data, are publicly available through the national archives. Data disposition is described in detail in the cruise reports below, and can be accessed directly through the OER Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm). Records of deep-sea corals and sponges observed with associated frame-grabs are available from the DSCRTP website (https://deepseacoraldata.noaa.gov/).

Kennedy, Brian; Messing, Charles; Amon, Diva (2019). Oceanographic data collected during the EX1711 Gulf of Mexico Mapping (ROV & Mapping) expedition on NOAA Ship OKEANOS EXPLORER in the Gulf of Mexico from 2017-11-29 to 2017-12-21 (NCEI Accession 0170751). NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/qsmk-bj73.

Pawlenko, Nikolai; Skarke, Adam; Wagner, Daniel (2019). Oceanographic data collected during the EX1803 Gulf of Mexico (ROV & Mapping) expedition on NOAA Ship OKEANOS EXPLORER in the Gulf of Mexico from 2018-04-11 to 2018-05-03 (NCEI Accession 0173643). NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/kzqv-3g66.

Highlight images, videos, educational materials, and descriptions of the accomplishments of the expedition are available via the expedition websites
https://ocean*Explorer*.noaa.gov/*Okeanos*/explorations/ex1711/welcome.html
https://ocean*Explorer*.noaa.gov/*Okeanos*/explorations/ex1803/welcome.html

Publications from project:

Maxon, A., Pawlenko, N., White, M., Skarke, A., Wagner, D., Cantelas, F., Jackson, L., Bowman, A. (2018). EX1803 Expedition Report: Gulf of Mexico 2018 (ROV/Mapping). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Cruise Report. EX1803. doi: doi.org/10.25923/ksxr-vj32

White, M. P., Kennedy, B. R. C., Amon, D., Messing, C., and Avila, A. M. (2020). Cruise Report: EX1711, Gulf of Mexico 2017 (ROV and Mapping). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Rep. 17-11. Doi: doi.org/10.25923/4yc3-an79

Images, maps, graphs, other key figures:

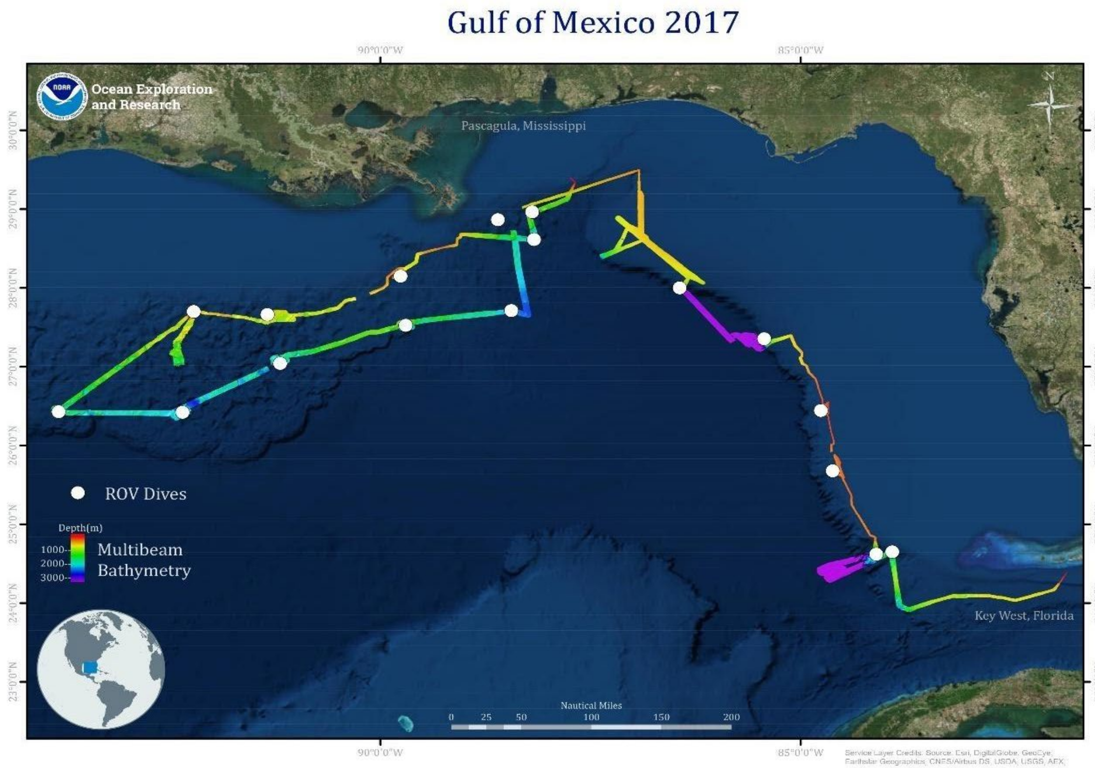


Figure 10. Cruise track with ROV dive locations and multibeam bathymetry for EX1711. Map: *NOAA OER*.

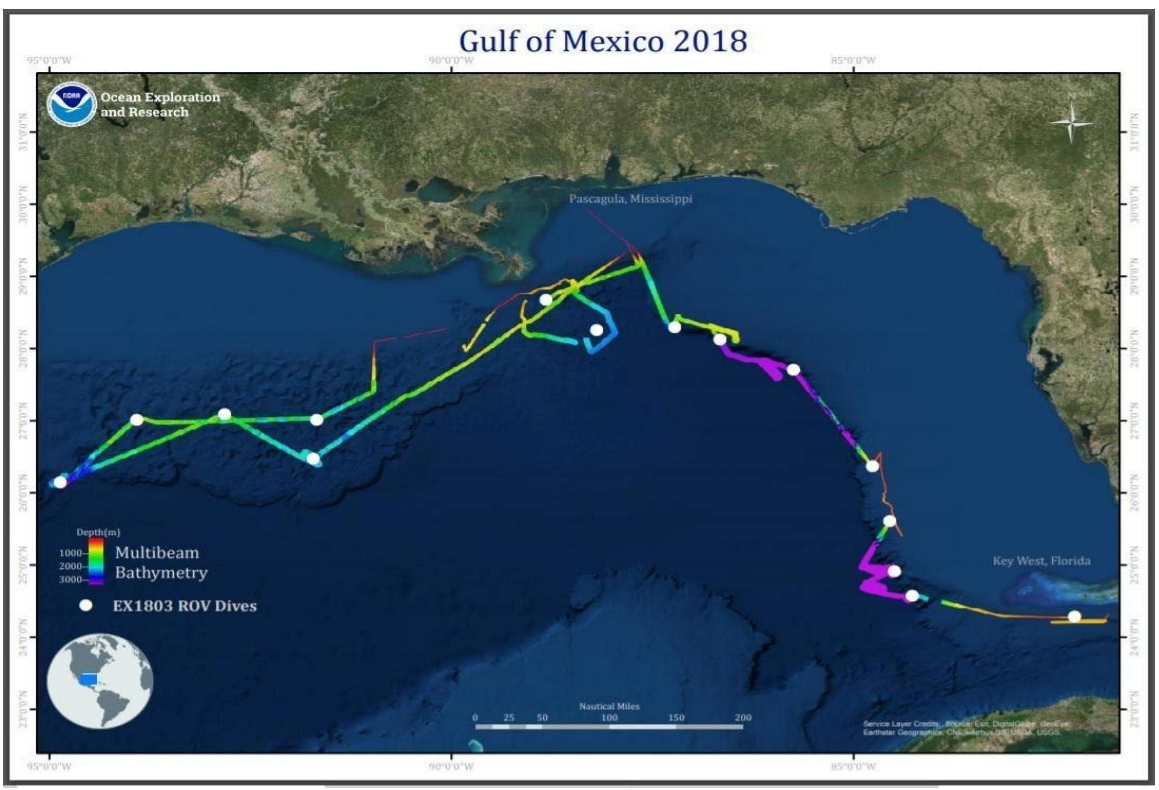


Figure 11. Cruise track with ROV dive locations and multibeam bathymetry for EX1803. Map: *NOAA OER*.

3.2.3 Density and Abundance of Corals and Sponges on West Florida Escarpment

Background and Objectives:

The continental shelf off the west coast of Florida is very broad, descending gradually over shelf margin carbonate mounds from 30 to 150 m depth (Locker et al., 2016), and then descending to 400 m depth where it drops more steeply over a small vertical escarpment adjacent to *Lophelia pertusa* mounds (Huebscher et al., 2010). Moving farther west, there is a large, steep escarpment at 1800 m that descends abruptly to 3500 m. Coral and sponge abundance and diversity was expected to vary considerably over this extreme range of depth and geology.

A series of missions in 2017 and 2018 explored two discrete depth ranges — 400-600 m, and 1500-3000 m. The purpose of the analyses was to determine how these different geological environments influence the abundance and diversity of sessile organisms. The *Lophelia* reefs along the West Florida Shelf are of particular conservation interest to the Gulf of Mexico FMC. The Council participated actively in the planning and execution of these surveys.

Approach:

NOAA Ship *Nancy Foster* explored the 400-600 m depth range off West Florida using ROV *Odysseus* from Pelagic Research Services (NF-17-08) aboard an 18-day expedition from St Petersburg, Florida to Charleston, South Carolina. The first leg was dedicated to ROV and CTD work, with mapping as a secondary objective. The second leg was a transit with no ROV, some mapping and CTD work, and an emphasis on outreach and education (Wagner et al., 2018). The team conducted 13 dives. An additional 11 ROV dives from five other expeditions within the same depth range and area were also included in the analysis (Table 2). The ROV dives transected flat areas, mound areas, and the 'ridge' escarpment from 400-450 m depth (Figure 12). Sea floor videos from these surveys were the subject of a Masters thesis by Zach Proux at College of Charleston (Proux, 2018). ROV tracks were used to estimate density over areas with discrete geological characteristics — namely mounds, ridges, and flat areas. In all transects, the ROVs maintained relatively constant speed and elevation off the seafloor (1-3 m), passed over a single habitat type (i.e., flat, mound, or ridge), and were limited to less than 100 m linear distance.

Seafloor video and images from eight NOAA Ship *Okeanos Explorer* dives in the depth range from 1500-3000 m aboard research cruises EX1711 and EX1803 (Figure 13), were analyzed separately by a Hollings Scholar named Morgan Will, an undergraduate from Nova Southeastern University. The analysis compared coral and sponge abundance and diversity against geological characteristics such as slope, depth and latitude. All ROV tracks were divided into 100-meter segments with distinct geologic characteristics. Screen captures of the ROV footage were taken at roughly 5-meter intervals throughout the segments, and corals and sponges in these screen captures were identified and counted. Segments were then assigned categories within each factor:

- Depth: 1500-2000 m, 2000-2500 m, and 2500-3000 m
- Latitude: North and South
- Substrate: Hard, Soft, and Mixed
- Slope: Horizontal, Vertical, and Mixed

Significant Results to Date:

Surveys of the West Florida Shelf had a timely and nearly immediate impact on conservation and management of coral ecosystems in this region. Council members witnessed the dives of ROV *Deep Discoverer* aboard NOAA Ship *Okeanos Explorer* live through telepresence technology. Because council members were able to view the seafloor through the camera on the ROV, they witnessed stunning examples of healthy deep-sea coral reef habitat over large areas that are both accessible and vulnerable to bottom-contact fishing gear.

Results from the West Florida field surveys were directly incorporated into Amendment 9 from the Gulf of Mexico FMC, particularly the surveys conducted in the 400-600 m depth zone over the Many Mounds reef system and adjacent ridge. The combined effect of these expeditions was the expansion and consolidation of three small areas into one contiguous area (48 sq km) called the West Florida Wall, one of the largest new HAPCs for deep-sea corals in the Gulf of Mexico.

On the West Florida Shelf, ROV footage from NOAA Ship *Okeanos Explorer* verified that ridges, flats, and mounds were present in all proposed HAPCs. Density and coral cover were measured; ridges and mounds had higher coral and sponge diversity (20-25 spp) than flat areas (17 spp) as well as higher density of sessile megafauna (Figures 14 and 15). There were many coral gardens (>50 colonies/100m^2, or >50% *Lophelia* cover in images) on mounds and ridges. *Lophelia* cover was 100% in some places. The potential *Lophelia* area is extensive and merits further exploration. Predominant organisms across all sites were gorgonians, black corals, stylasterids, and demosponges, with only slight variation in relative proportions among sites (Figure 16).

On the West Florida escarpment, while depth and substrate varied significantly with variations in coral and sponge diversity and abundance, latitude and slope did not. The 1500-2000 m taxa were over 50% Alcyonacea, while the 2500-3000 m taxa were over 30% Scleractinia, with Hexactinellida and Alcyonacea being the second and third most abundant, respectively. The overall abundance of corals and sponges was much lower at 2500-3000 m compared to 1500-2000 m (Figure 17). Regarding substrate, hard substrate taxa were over 50% Alcyonacea, while soft substrate taxa were over 50% Hexactinellida, with Pennatulacea being the next largest group. The overall abundance of corals and sponges was much lower in the soft substrate than the hard substrate, as expected.

This was the first comparison of diversity and abundance along deep West Florida Escarpment. Forty morpho-taxa were identified with the most common coral families on hard sediment being Isididae, Antipathidae, and Chrysogorgidae. The most common coral families on soft substrate were Isididae, Umbellulidae, and Antipathidae.

For future surveys, CTDO (conductivity, temperature, depth, oxygen) data should be joined to observations in the visual data to help explain the patterns observed in this preliminary study. More surveys are needed in this area to study the effect of proximity to sediment and current flow on species assemblages and ensure that communities on all geological and special variations are documented.

Point of Contact:

Peter Etnoyer (peter.etnoyer@noaa.gov), NOAA NCCOS Marine Spatial Ecology Division (MSE)

Additional Collaborators:

Zach Proux, College of Charleston, Daniel Wagner, NOAA NCCOS MSE, and Morgan Will, Nova Southeastern University

References and document links:

Hübscher, C., Dullo, C., Flögel, S., Titschack, J., & Schönfeld, J. (2010). Contourite drift evolution and related coral growth in the eastern Gulf of Mexico and its gateways. International Journal of Earth Sciences, 99(1), 191-206.

Locker, S. D., Reed, J. K., Farrington, S., Harter, S., Hine, A. C., & Dunn, S. (2016). Geology and biology of the "Sticky Grounds", shelf-margin carbonate mounds, and mesophotic ecosystem in the eastern Gulf of Mexico. Continental Shelf Research, 125, 71-87.

Publications from project:

Wagner, D., M. Kilgour, and P.J. Etnoyer. 2018. Expedition Report: 2017 Southeast Deep Coral Initiative (SEDCI) expedition aboard NOAA Ship *Nancy Foster* (NF-17-08: August 12-31, 2017). NOAA Technical Memorandum NOS NCCOS 244. Charleston, SC. 130 pp. doi.org/10.7289/V5/TM-NOS-NCCOS-244

Proux, Zach. 2018. Assessing the relationship between geomorphology and species composition on the West Florida Shelf. College of Charleston. Masters thesis in Marine Biology.

Will, Morgan. Diversity and Abundance of Deep Sea Corals and Sponges in the Bathyal Terrain of West Florida Escarpment. NOAA Mission Goal: Healthy Oceans. Poster presented at the Ocean Sciences Meeting, Feb 16-21, 2020, San Diego, CA.

Images, maps, graphs, other key figures:

Table 2. Surveys included in Proux 2018 with dates and number of ROV dives in the study area.

Survey ID	Vessel	ROV	Dates in Study Area	# Dives
FK004E	R/V *Falkor*	*Global Explorer*	8/31/2012 - 9/1/2012	2
FK006C	R/ V *Falkor*	*Global Explorer*	12/9/2012 - 12/12/2012	3
EX1402_L3	NOAA Ship *Okeanos Explorer*	*Deep Discoverer*	4/28/2014 - 4/29/2014	2
NF1708	NOAA Ship *Nancy Foster*	*Odysseus*	8/13/2017 - 8/23/2017	12
EX1711	NOAA Ship *Okeanos Explorer*	*Deep Discoverer*	12/2/2017 - 12/3/2017	2
EX1803	NOAA Ship *Okeanos Explorer*	*Deep Discoverer*	4/28/2018 - 4/29/2018	2

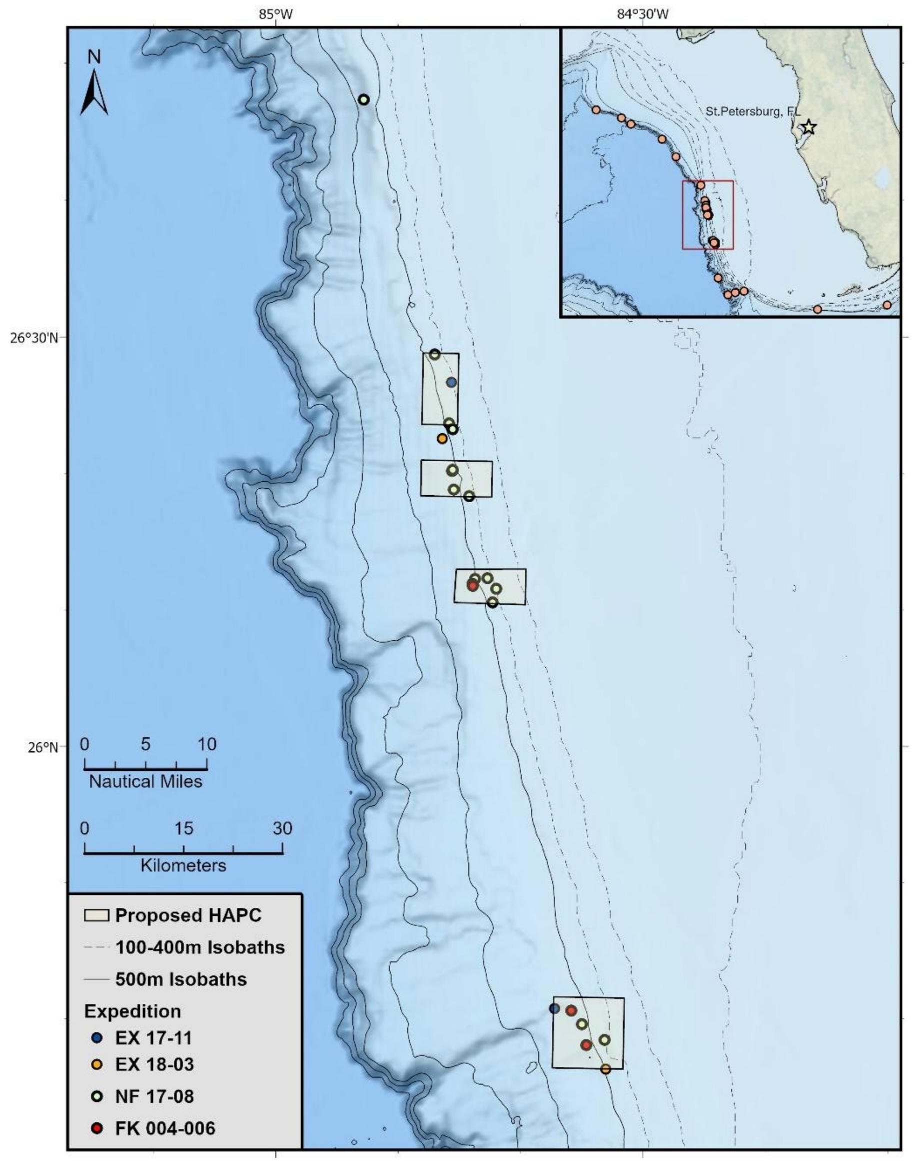


Figure 12. Map of the 2017 ROV dive sites in four proposed HAPCs (at that time) on the West Florida Shelf.

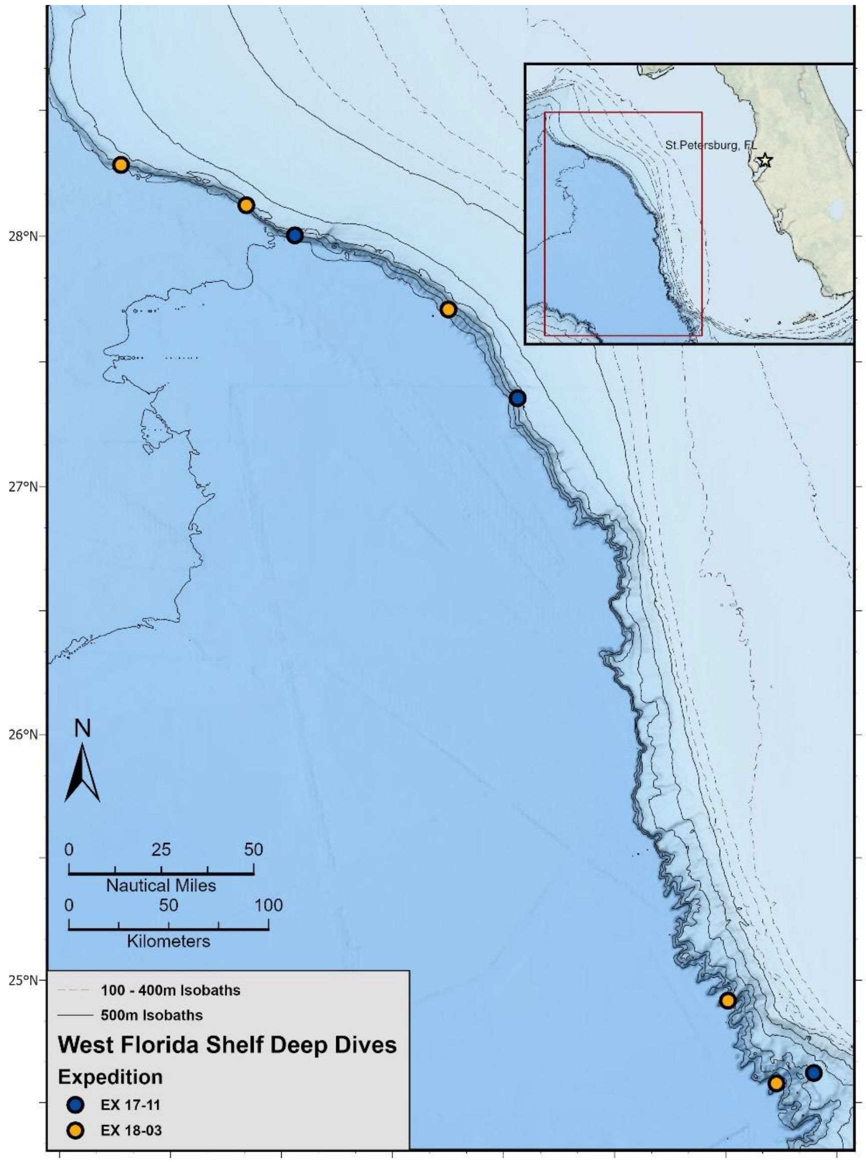


Figure 13. Location of the eight NOAA Ship *Okeanos Explorer* dives on the West Florida escarpment used for the analysis to compare coral and sponge abundance and diversity against geological characteristics.

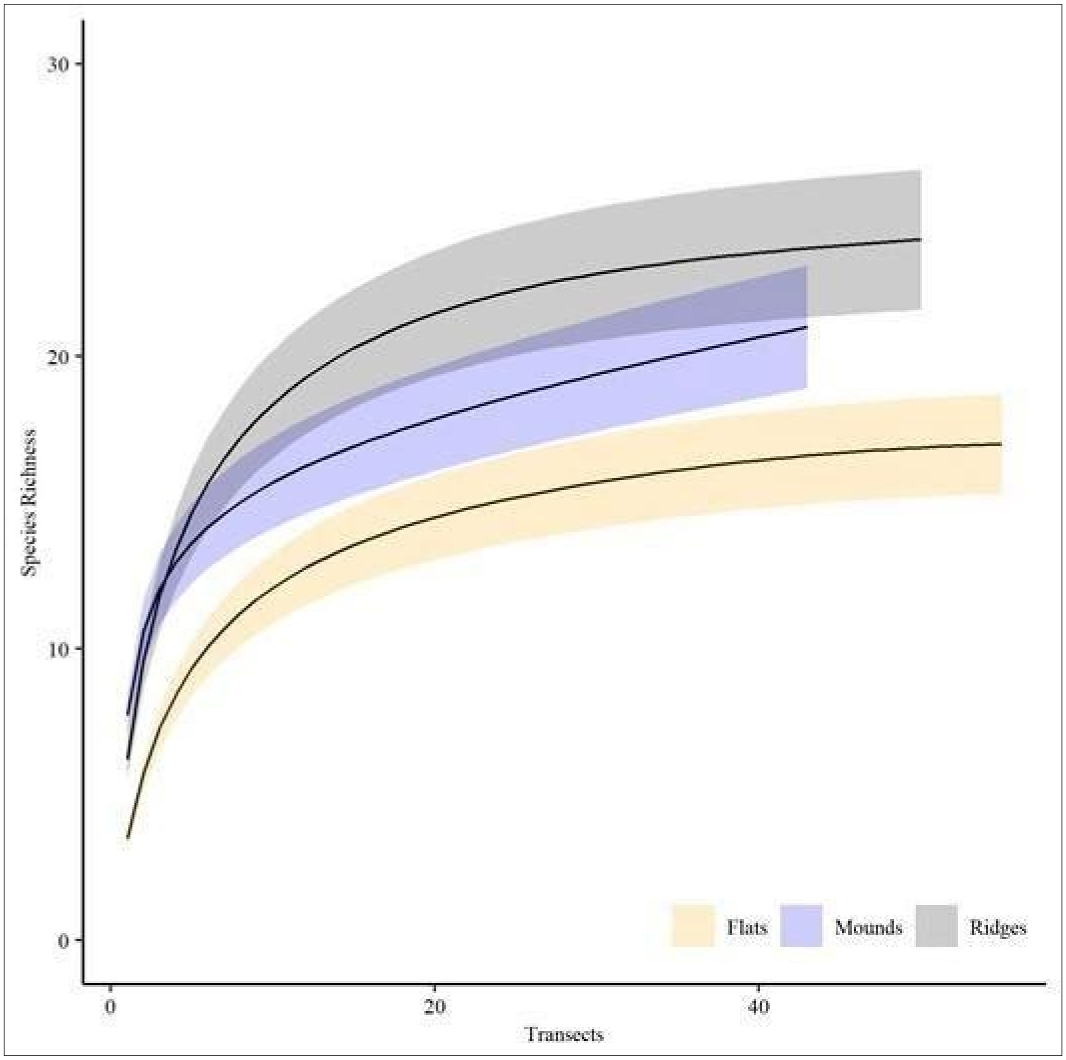


Figure 14. Species richness on flats, mounds, and ridges as a function of number of sites surveyed. Colored ribbons represent ± (2*standard deviation).

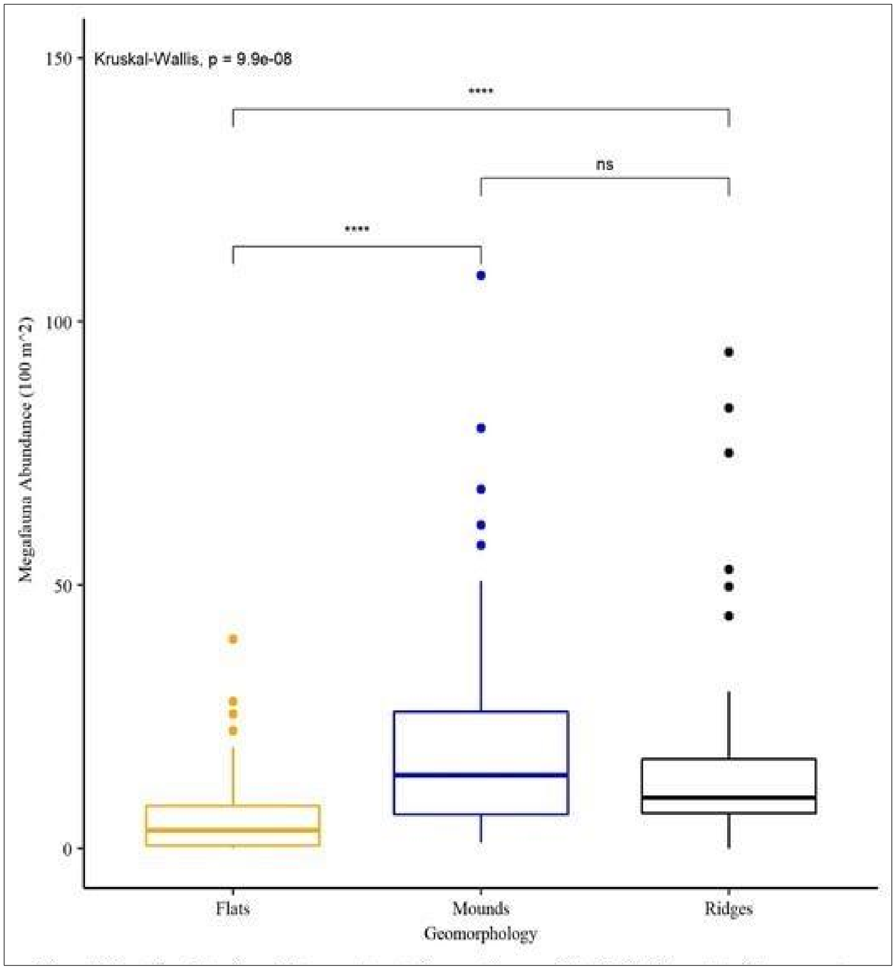


Figure 15. Density of sessile megafauna on flats, mounds and ridges on the upper West Florida Slope. Asterisks represent significance levels, ns = not significant.

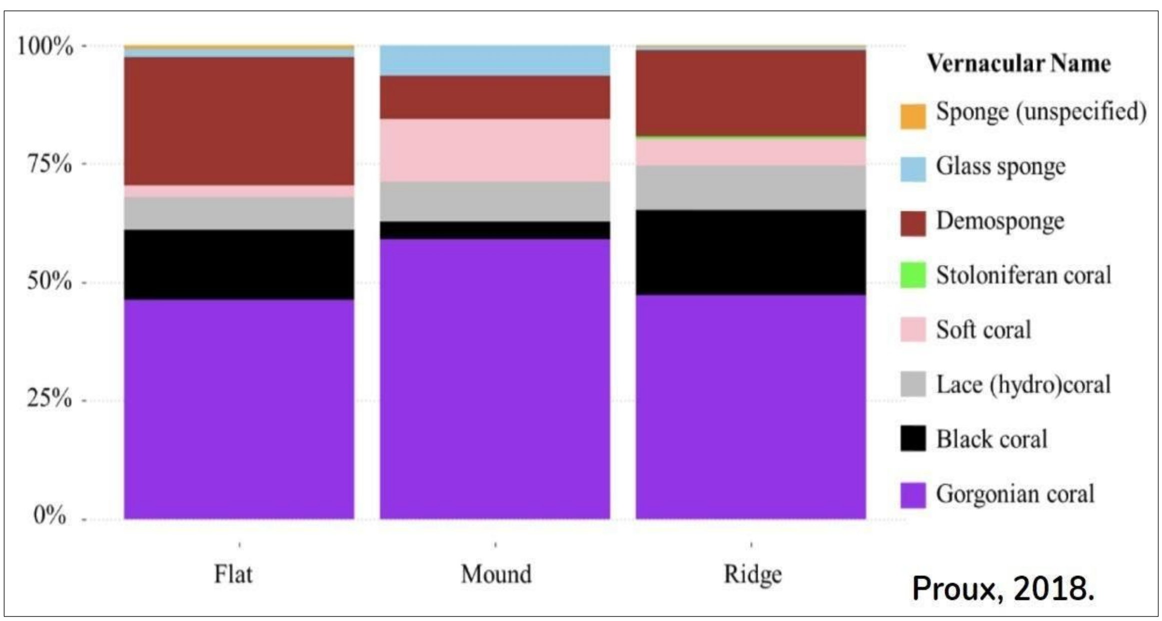


Figure 16. Abundance of eight taxonomic groups on the three geomorphologic features within the study.

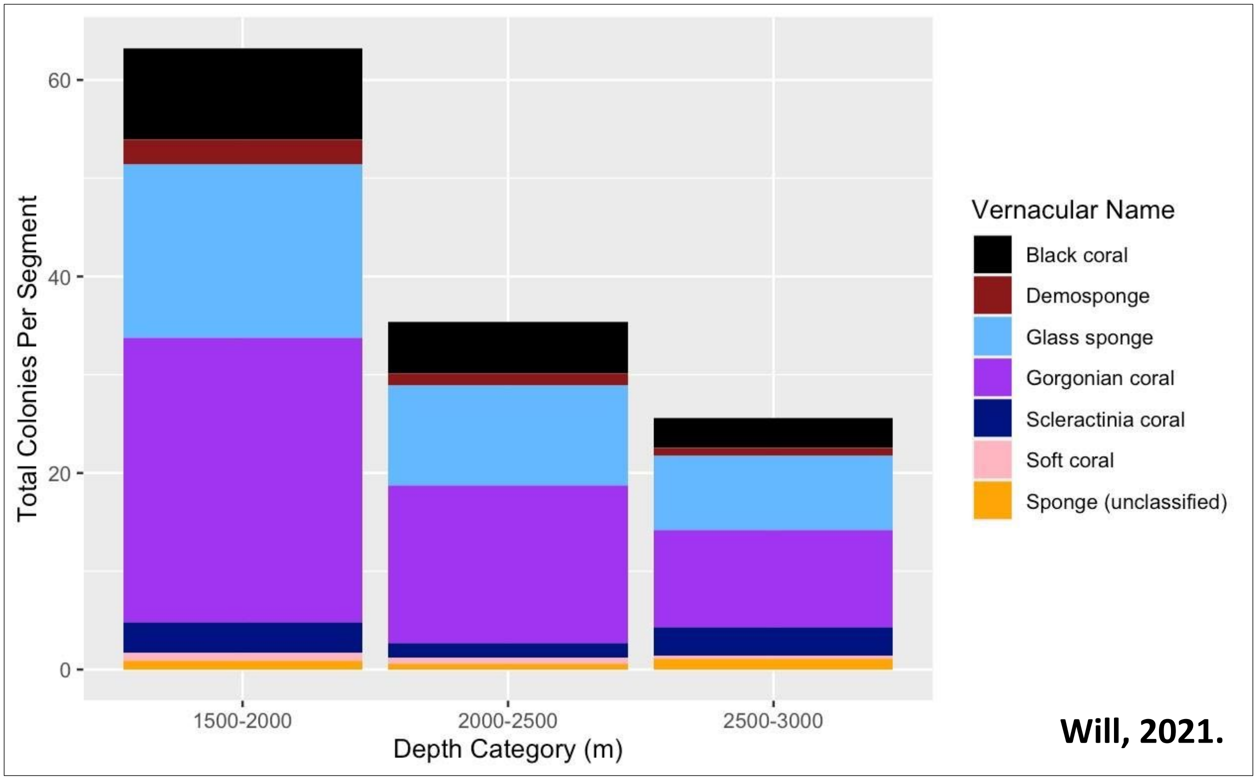


Figure 17. Abundance of seven taxonomic groups within the three depth categories within the study.

3.3 SEDCI Fieldwork in the Southeast U.S.

The main goals for the Southeast U.S. region (South Atlantic Council region) were mapping unexplored areas of interest and studying biological and ecological aspects of deep-sea coral ecosystems in HAPCs to better understand fishing effort in these areas. In addition to meeting these goals, fieldwork projects also included undersea canyon exploration, and habitat characterization of some of the South Atlantic Council's Deepwater Marine Protected Areas. Through a partnership with DEEP SEARCH, SEDCI also helped fund the characterization of 85-miles of *Lophelia pertusa* reefs off the coast of South Carolina.

Images, maps, graphs, other key figures:

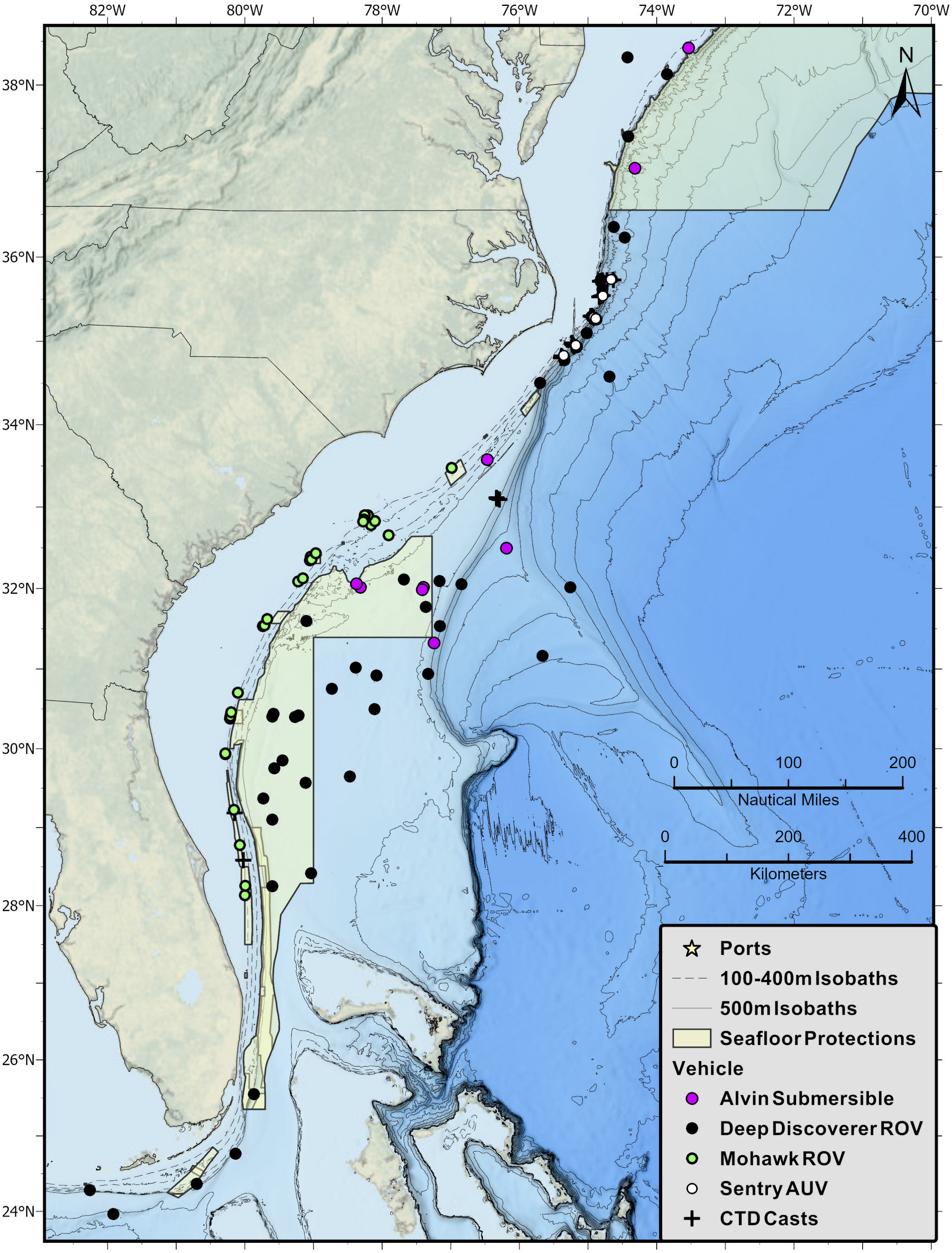


Figure 18. Locations of SEDCI and partner dives and CTD casts performed off the Southeast U.S. from 2016-2019.

3.3.1 Exploring Carolina Canyons off the Southeast Coast of the U.S.

Background and Objectives:

Submarine canyons continue to be areas of high interest to the scientific community, as well as federal and state agencies with resource management responsibilities, particularly those related to deep-sea corals. The biota of most canyons is poorly known, but based on data collected during previous investigations, many scientists and managers believe submarine canyons provide refuge for a variety of fauna, including deep-sea corals, other invertebrates, and fishes. In an effort to explore and survey a variety of habitats likely to support deep-sea corals, submarine canyons were given high priority among study sites proposed for surveys during the SEDCI. Two expeditions, dedicated solely to major canyons located off the coast of North Carolina (Figure 19), were undertaken with the overall objective to survey suspected deep-sea coral habitats associated with deepwater canyons. Specifically, these expeditions sought to:

- Survey canyon and inter-canyon slope habitats to characterize benthic habitats and identify areas of coral presence
- Conduct mapping operations in areas where multibeam data were missing or incomplete
- Assess geological features and characterize canyon morphology
- Collect CTD data, as well as sediment and water sample
- Assemble a database of seafloor photographs to identify benthic species and assess faunal diversity, abundance and distributions
- Assemble maps of geo-referenced coral locations and associated data

Approach:

The team collected multibeam bathymetry to identify areas with topographic features (i.e., high slope areas) known to support deep-sea coral communities in other regions. Dive tracks were then designed to survey these areas with high probability of coral presence. At each station, we deployed Woods Hole Oceanographic Institution's AUV *Sentry*, which collected images of the seafloor (taking one photo every 3 seconds) throughout the dive. Non-overlapping, georeferenced images were analyzed for coral and sponge presence as well as substrate type. Corals and sponges were quantified and identified to the lowest possible taxon.

Significant Results to Date:

Documented presence of a diversity of coral species in areas of high slope supported the use of multibeam bathymetry to identify topographic features to guide sampling surveys. However, extreme conditions (i.e., steep walls, rocky outcrops, high currents) within the canyons significantly limited the ability of the AUV to maneuver close to canyon walls. Thus, overall image quality was poor given the distance off bottom as well as distance away from vertical obstructions required for safe operation of the vehicle. These results suggest this type of AUV is not suitable sampling gear for canyon environments. Nevertheless, some observations and comparisons between the major canyons surveyed can be gleaned from the data collected. Corals and sponges were observed in each canyon (Figures 20a-d) surveyed, though no areas supporting high-density aggregations were observed. Sponges, in particular, were uncommon. Soft substratum was the most common substrate type observed in both Hatteras and Pamlico canyons. However, coral diversity and frequency of occurrence differed between these canyons. The sea pen *Kophobelemnon* sp. was the numerically dominant species in Hatteras Canyon (Figure 21a) accounting for 57% of coral observations. In contrast, unidentified Scleractinia (primarily solitary cup corals) and *Acanthogorgia* sp. accounted for 65% of coral observations in Pamlico Canyon (Figure 21b). Observations appear to support the hypothesis that submarine canyons have their own biological and geological signature.

Point of Contact:

Martha Nizinski (Martha.Nizinski@noaa.gov), NOAA Fisheries' Office of Science and Technology, National Systematics Lab

References and document links:

The 2016 cruise was designated a NOAA OER signature cruise and part of the ASPIRE campaign: http://ocean*Explorer*.noaa.gov/explorations/16carolina/welcome.html.

The 2017 cruise was featured on an expedition website hosted by the North Carolina Museum of Natural Sciences: naturalscienceseducation.wordpress.com/category/online-adventures/carolina-canyons/.

Publications from project:

Nizinski, MS and M Rhode. (202X - planned) Site characterization and dive summary reports for Southeast US submarine canyons explored in years 2016 - 2017 - Hatteras, Pamlico, and Keller Canyons. NOAA Technical Memorandum.

Images, maps, graphs, other key figures:

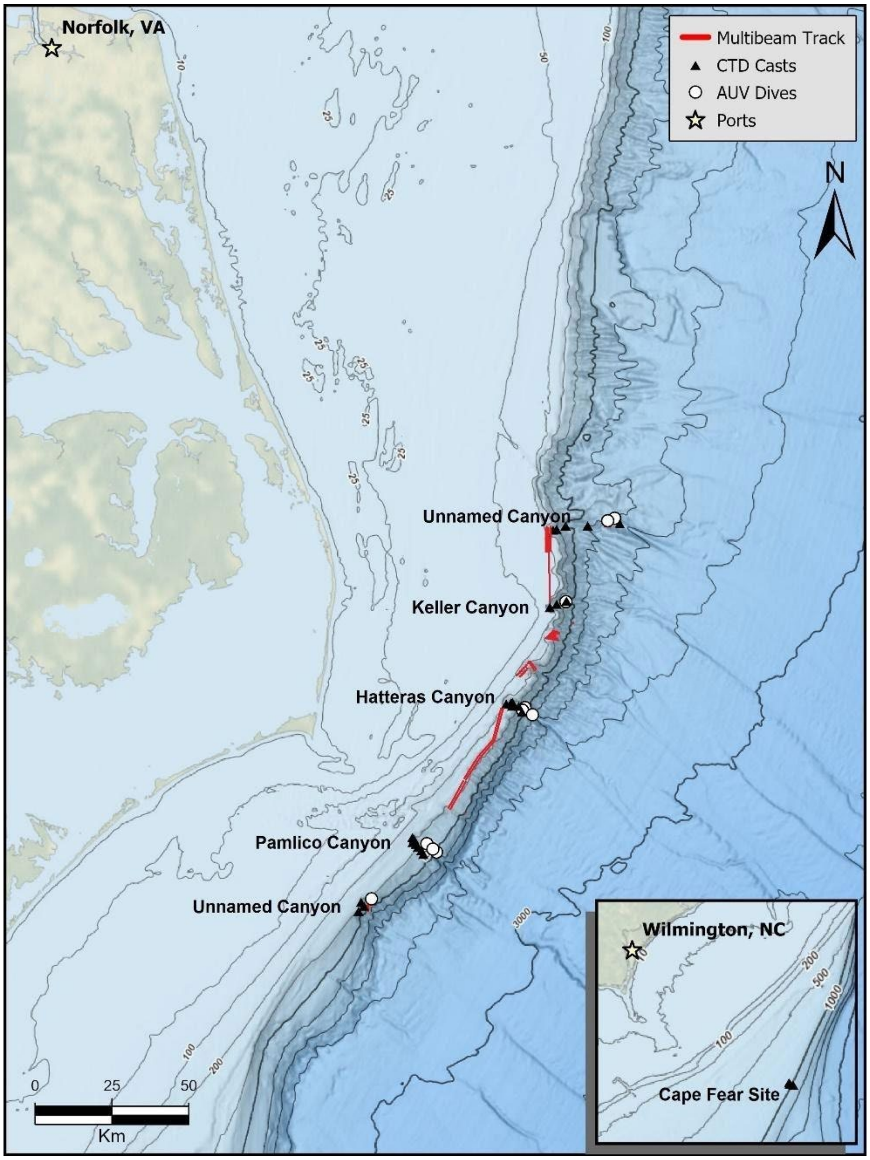
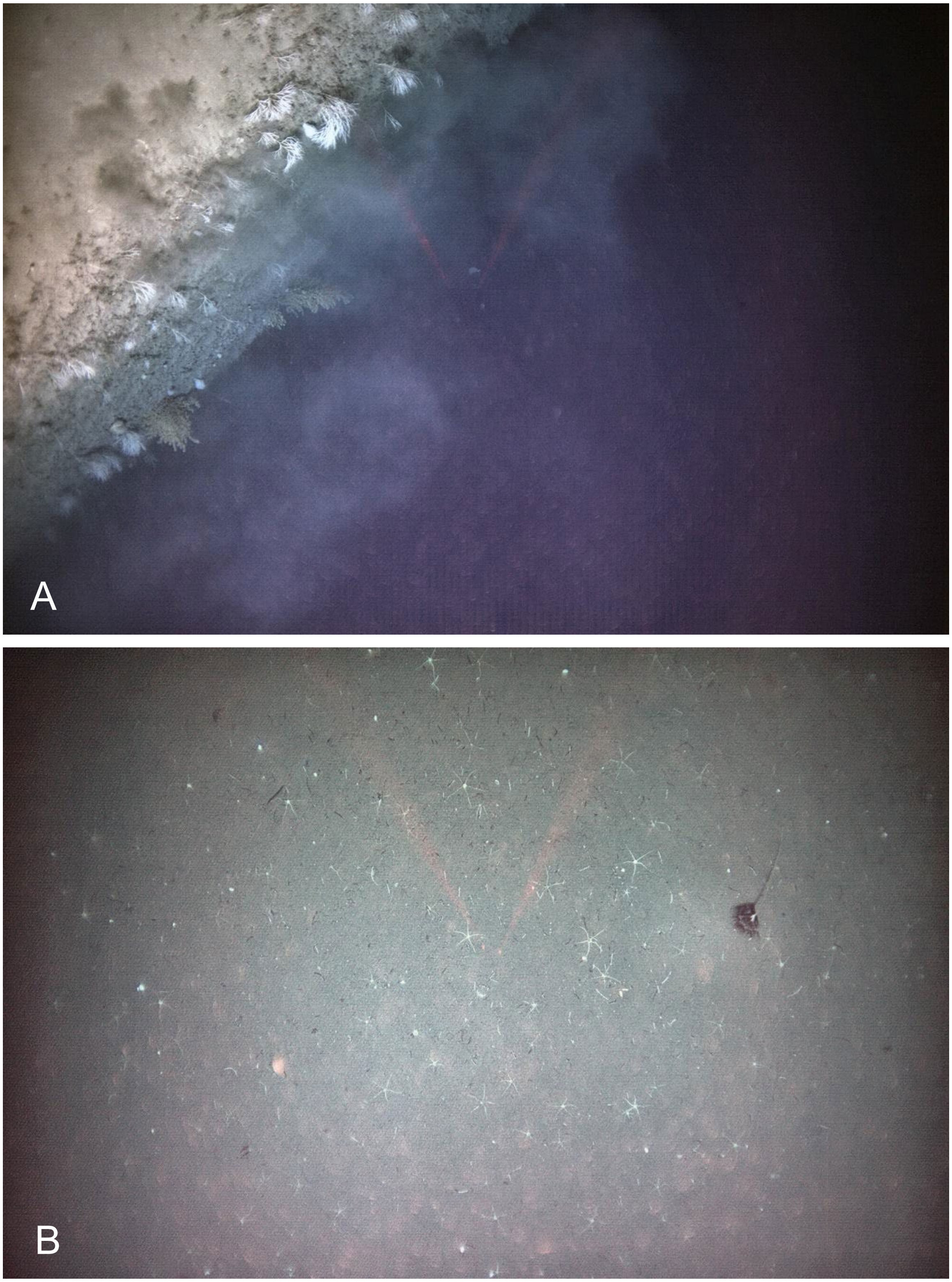
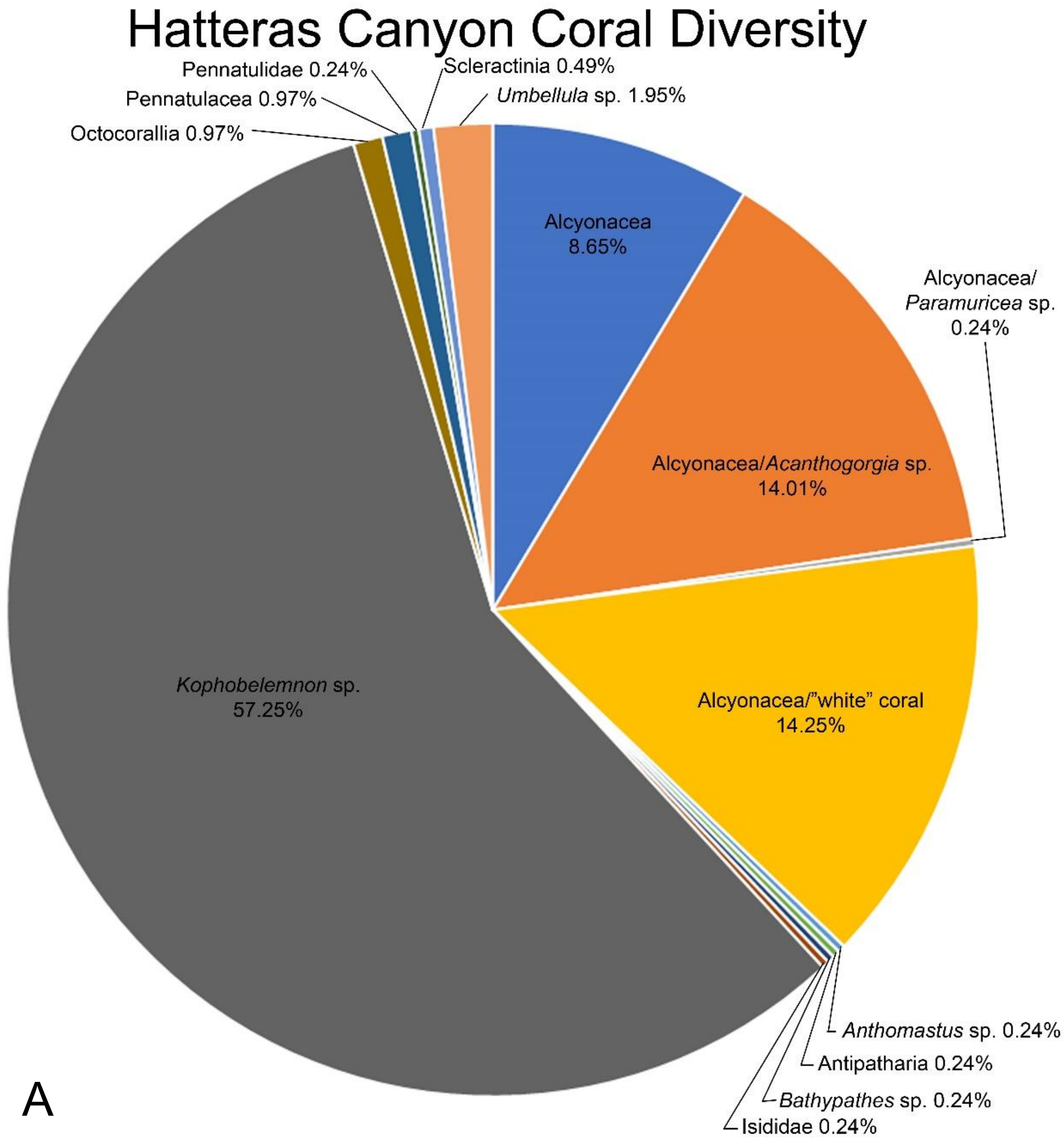


Figure 19. Map showing the operational area of the two project expeditions aboard NOAA Ship *Pisces* (PC-16-05 and PC-17-04) that surveyed deep-sea coral ecosystems in canyons off the North Carolina coast using AUV *Sentry*, multibeam mapping and CTD casts.



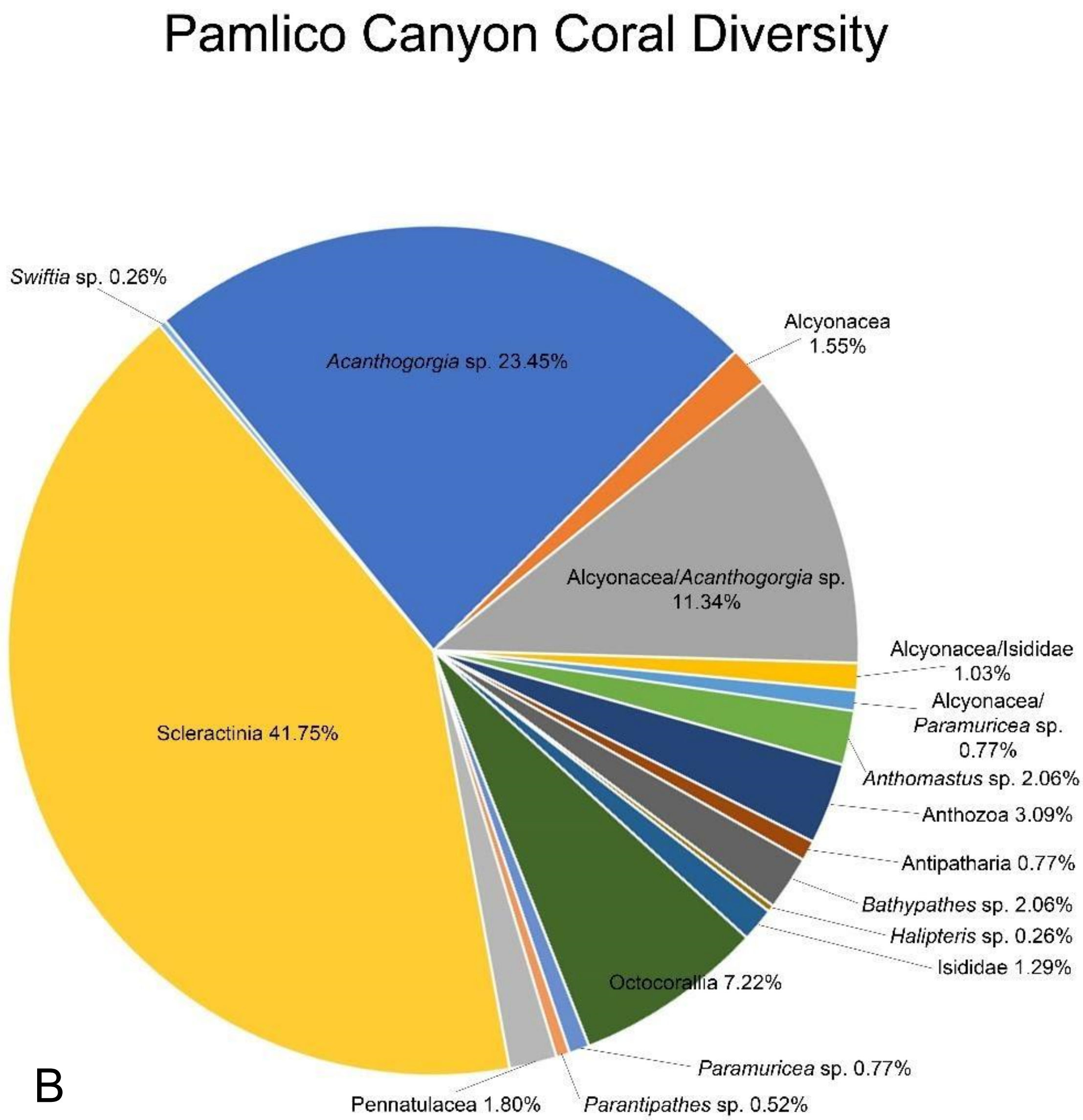
Figures 20a-b. Example images from Hatteras Canyon.

Figures 20c-d. Example images from Pamlico Canyon.



Color	Coral	Number	Color	Coral	Number
	Alcyonacea	71		Isididae	2
	Alcyonacea/*Acanthogorgia* sp.	115		*Kophobelemnon* sp.	470
	Alcyonacea/*Paramuricea* sp.	2		Octocorallia	8
	Alcyonacea/ "white" coral	117		Pennatulacea	8
	Anthomastus sp.	2		Pennatulidae	2
	Antipatharia	2		Scleractinia	4
	Bathypathes sp.	2		*Umbellula* sp.	16

Figure 21a. Pie graph illustrating the number of coral taxa identified and enumerated from non-overlapping digital stills in Hatteras Canyon. Each color in the graph represents the proportion of digital stills where a species was present.



Color	Coral	Number	Color	Coral	Number
	Acanthogorgia sp.	91		*Halipteris* sp.	1
	Alcyonacea	6		Isididae	5
	Alcyonacea/*Acanthogorgia* sp.	44		Octocorallia	28
	Alcyonacea/Isididae	4		*Paramuricea* sp.	3
	Alcyonacea/*Paramuricea* sp.	3		*Parantipathes* sp.	2
	Anthomastus sp.	8		Pennatulacea	7
	Anthozoa	12		Scleractinia	162
	Antipatharia	3		*Swiftia* sp.	1
	Bathypathes sp.	8			

Figure 21b. Pie graph illustrating the number of coral taxa identified and enumerated from non-overlapping digital stills in Pamlico Canyon. Each color in the graph represents the proportion of digital stills where a species was present.

3.3.2 NOAA Ship *Okeanos Explorer* Expeditions in the Southeast U.S.

Background and Objectives:

In 2018 and 2019, NOAA OER supported several multi-phase expeditions that contributed to the Atlantic Seafloor Partnership for Integrated Research and Exploration (ASPIRE) campaign and helped to meet SEDCI objectives: Windows to the Deep 2018 (EX1805 and EX1806), Windows to the Deep 2019 (EX1903L1 and EX1903L2), and 2019 Southeastern U.S. Deep-sea Exploration (EX1906 and EX1907). Over a combined total of 118 days at sea, OER and partners conducted telepresence-enabled ocean exploration expeditions on NOAA Ship *Okeanos Explorer* to collect critical baseline data and information and to improve knowledge about unexplored and poorly understood deepwater areas of the Southeast U.S. continental margin. The goal of all expeditions was to survey deepwater areas offshore of Florida, Georgia, South Carolina, and North Carolina in order to provide baseline data and information to support management and science needs. SEDCI provided quantitative annotations of deep-sea corals and sponges encountered on all dives of these expeditions. Data from these expeditions will help to improve our understanding of the deep-ocean habitats of the U.S. continental margin and of the connections between communities throughout the Atlantic Basin.

Specific SEDCI-relevant ASPIRE objectives included the following:

- Acquire data on deepwater habitats in the southeast and mid-Atlantic U.S. continental margin to support priority science and management needs
- Identify, map, and explore the diversity and distribution of benthic habitats, including fish habitats and deep-sea coral and sponge communities
- Investigate biogeographic patterns of deep-sea ecosystems and connectivity across the Southeast U.S. continental margin for use in broader comparisons of deepwater habitats throughout the Atlantic Basin
- Map, survey, and sample geologic features within the Southeast U.S. continental margin to better understand the geological context of the region and improve knowledge of past and potential future geohazards
- Collect high-resolution bathymetry in areas with no (or lower quality) mapping data;
- Acquire a foundation of ROV, sonar, and oceanographic data to better understand the characteristics of the water column
- Provide a foundation of publicly accessible data and information products to spur further exploration, research, and management activities

Approach:

Each two-part expedition used the ship's deepwater mapping systems (Kongsberg EM304 multibeam sonar, Simrad EK60 and EK80 split-beam fisheries sonars, Knudsen 3260 chirp sub-bottom profiler sonar, and Teledyne Acoustic Doppler Current Profiler [ADCP]), NOAA's dual-body deepwater ROV, and a high-bandwidth satellite connection for real-time ship to shore communications In total, the three expeditions conducted 48 ROV dives in depths ranging from 325 to 3,498 m over 64 days at sea, and included midwater exploration in depths ranging from 300 to 1,000 m. In total, 398 biological samples and 60 geological samples were collected. All expeditions contributed to the ASPIRE campaign, a major multi-year, multi-national collaborative field program focused on raising collective knowledge and understanding of the North Atlantic.

Significant Results to Date:

During the 17 ROV dives of EX1806 (Figure 22), the 19 ROV dives of EX1903L2 (Figure 23), and the 12 ROV dives of EX1907 (Figure 24), hundreds of species of animals were observed, including several potential new species, new records for the region, and several significant range extensions. Several organisms were also seen alive for the first time. Mapping and ROV surveys on the Blake Plateau revealed an exceptional and diverse deep-sea scleractinian coral mound province – which recent analyses (Sowers 2020) suggest may be may represent the largest such coral mound province in the world. Relevant highlights include:

EX1806

- EX1806 collected six biological samples to support trans-Atlantic connectivity studies including *Geodia pachydermata, Bathypathes* sp., *Leiopathes* sp., *Anthomastus* sp., *Lophelia pertusa,* and *Phronima* sp.
- EX1806 revealed one of the largest continuous areas of deep-sea coral reef habitat discovered in U.S. waters to date. Through mapping and visual surveys, this expedition added substantial evidence that the numerous mounds on the Stetson Mesa offshore of Florida and Georgia appear to be a product of extensive accumulation of *Lophelia pertusa* coral skeletal material over hundreds of thousands of years. This expedition explored three mounds. All were rich with live coral stands at their crests. Subsequent analysis of the mapping data in this region by OER has estimated the area of a nearly continuous cold-water coral mound province covering approximately 28,000 sq km in this region (D. Sowers, personal communication, June 2, 2021).
- EX1806 conducted ROV dives and mapping operations in two areas managed by the South Atlantic FMC—the Stetson Miami Terrace Deepwater Coral HAPC and Cape Fear Lophelia Banks Deepwater Coral HAPC.
    - When coupled with EX1805, this expedition mapped over 7,400 sq km and conducted three dives in the Stetson Miami Terrace HAPC that revealed high-density coral communities at each site.
    - An ROV dive in the Cape Fear HAPC documented several large wreckfish (*Polyprion americanus*), a commercially important species managed by the South Atlantic FMC.
- EX1806 discovered a high diversity of deep-sea corals and sponges on low relief, intraslope terraces (terraced features between 1,000 and 4,000 m) along the Blake Escarpment in areas with no previous exploration.
- EX1806 documented three dive sites with relatively high biological diversity and six medium diversity sites. Six dive sites had high biological abundance/density or high biomass. Deep-sea corals and sponges were observed on every dive except one, which was a dedicated gas seep exploration dive.
- EX1806 observed several potential new species, recorded significant depth and geographic range extensions for several fish and coral species, and documented the presence of commercially important species—including red crab (*Chaceon quinquedens*) and golden crab (*Chaceon fenneri*)—in areas not previously investigated.

EX1903L2

- Conducted six ROV dives and mapped in Stetson Miami Terrace Deepwater Coral HAPC.
    - Mapped over 4,860 sq km (5,405 sq miles), bringing the total OER-supported bathymetry collected since 2011 within the HAPC to 34,037 sq km (13,142 sq miles).
    - Expanded our knowledge of the "Million Mounds" region of the Stetson Miami Terrace Deepwater Coral HAPC, an area nicknamed for the many mounding

features that comprise one of the largest areas of deep-sea coral reef habitats that have been discovered in U.S. waters to date.
    - The two legs of EX1903 gathered bathymetry over the “Million Mounds” bathymetry over the “Million Mounds” region of the HAPC, and revealed the first indication of an eastern boundary of this habitat. ROV exploration revealed extensive deep-sea coral and sponge habitat, including five sites with highly diverse communities.
- EX1903L2 conducted the first mapping (on Legs 1 and 2) and ROV exploration of a portion of the central Blake Plateau, where previously unknown mound features were discovered. Two ROV dives documented expansive live coral communities, and confirmed that these features were likely created by the accumulation of *Lophelia pertusa* skeletal matrix over time. Prior to this expedition, this area of the Plateau was thought to be flat, featureless, and composed primarily of soft sediment.
- Collected three biological samples to support trans-Atlantic connectivity studies including *Anthomastus sp.*, *Lophelia pertusa,* and *Bathymodiolus childressi.*
- Deployed a new suction sampler, allowing ROV *Deep Discoverer* to collect mobile fauna for the first time. 30 samples were collected using the new suction sampler, including cephlapods, jellyfish, siphonophores, ctenophores, and difficult to sample associates of deep-sea corals.
- Documented ten dive sites with high biological diversity and observed deep-sea corals and sponges on 18 ROV dives.
- Observed several potential new species, recorded significant depth and geographic range extensions for several species, and documented the presence of commercially important species - including wreckfish (*Polyprion americanus*), Atlantic roughy (*Hoplostethus occidentalis*), red crab (*Chaceon quinquedens),* golden crab (*Chaceon fenneri*), and a large aggregation of Alfonsino *(Beryx decadactylus)* - in areas not previously investigated.

EX1907

- Deep-sea (cold water) corals and sponges were observed on all 12 of the ROV dives.
- Documented high-density communities of deep-sea corals and sponges on three dives:
    - Stetson Mesa, Million Mounds East (Dive 02) —A coral garden was explored in an area that may mark the eastern extent of the Million Mounds region.
    - Isolated Mound, Central Blake Plateau (Dive 06) —Two previously unknown *Lophelia pertusa* mounds measuring more than 60 m (197 feet) tall were discovered and explored. These features, which are outside of a HAPC, were targeted for exploration based on mapping data collected during the first leg of the expedition.
    - Pourtalès Terrace (Dive 10) — Terrace-like plateaus and overhangs, which harbored life on both the top surfaces and the undersides were explored. Among the many highlights was an abundance of *Gorgonocephalus* sp. (basket stars); 10 were documented.
- Conducted ROV dives in two HAPCs managed by the South Atlantic FMC:
    - Stetson-Miami Terrace Deepwater Coral HAPC (six dives) - Expanded knowledge about the eastern boundary of the Million Mounds region.
    - Pourtalès Terrace Deepwater Coral HAPC (one dive) - Explored both inside and outside of the protected area.
- Mapped more than 94,000 sq km of seafloor over the course of the three expeditions.

Point of Contact:

Caitlin Adams (caitlin.adams@noaa.gov), NOAA OER

References and document links:

All data collected during the expeditions, including video and environmental data collected on every ROV dive, mapping data, oceanographic and meteorological data, have been made publicly available through national archives. Data disposition is described in detail in the cruise reports below, and can be accessed directly through the OER Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm). Records of deep-sea corals and sponges observed with associated frame-grabs are available from the DSCRTP website (https://deepseacoraldata.noaa.gov/).

Cantwell, Kasey; Morrison, Cheryl; Sautter, Leslie (2019). Oceanographic data collected during the EX1806 Mid and Southeast US (ROV & Mapping) expedition on NOAA Ship OKEANOS EXPLORER in the North Atlantic Ocean from 2018-06-11 to 2018-07-02 (NCEI Accession 0177758). NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/51yt-b051.

Cantwell, Kasey; Wagner, Amy; Weinnig, Alexis (2019). Oceanographic data collected during the EX1903L2 Mid and Southeast US (ROV & Mapping) expedition on NOAA Ship OKEANOS EXPLORER in the North Atlantic Ocean from 2019-06-20 to 2019-07-12 (NCEI Accession 0195408). NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/aajk-1b71.

Farrington, Stephanie; Galvez, Kimberly; White, Michael (2019). Oceanographic data collected during the EX1907 Mid and Southeast US (ROV and Mapping) expedition on NOAA Ship OKEANOS EXPLORER in the North Atlantic Ocean from 2019-10-31 to 2019-11-21 (NCEI Accession 0207829). NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/j30w-ac52.

Highlight images, videos, educational materials, and descriptions of the accomplishments of the expedition are available via the expedition websites

https://ocean*Explorer*.noaa.gov/*Okeanos*/explorations/ex1806/welcome.html

https://ocean*Explorer*.noaa.gov/*Okeanos*/explorations/ex1903/welcome.html

https://ocean*Explorer*.noaa.gov/*Okeanos*/explorations/ex1907/welcome.html

Publications from project:

Cantwell, K, Wagner, A., Weinnig, A., Hoy, S., Dunn, C.J., & Copeland, A. (2019). EX1903L2: Windows to the Deep 2019 Cruise Report. Office of Ocean Exploration and Research, Office of Oceanic & Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Rep. 19-03-2, 52 p. doi.org/10.25923/9ry2-fn95

Cantwell, K, Sautter, L., Morrison, C., Sowers, D., and Bowman, A. (2020). Cruise Report: EX-18-06, Windows to the Deep 2018 (ROV & Mapping). Office of Ocean Exploration and Research, Office of Oceanic & Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Rep. 18-06, 67 p. doi.org/10.25923/50hx-3p68

Hoy, S., Power, D., and Jerram. A. (2019). Mapping Data Acquisition and Processing Summary Report: Cruise EX-19-03 Leg2 Windows to the Deep 2019. Office of Ocean Exploration and Research, Office of Oceanic & Atmospheric Research, NOAA, Silver Spring, MD 20910, 23p., doi.org/10.25923/g4nq-3z59

Hoy, S., Wilkins, C., and Peters, C. (2019). Mapping data acquisition and processing summary report: EX-19-07: 2019 Southeastern U.S deep-sea exploration (rov/mapping). Office of Ocean Exploration and Research, Office of Oceanic & Atmospheric Research, NOAA, Silver Spring, MD 20910, 21p., doi.org/10.25923/xyzy-ss85

Lobecker, M., Bittinger, A. (2020). Mapping Data Acquisition and Processing Summary Report: EX-18-05, East Florida and DEEP SEARCH Mapping (Mapping). Office of Ocean Exploration and Research, Office of Oceanic & Atmospheric Research, NOAA, Silver Spring, MD 20910, 36p., doi.org/10.25923/7wfg-h781

Sowers, D., Wilkins, C., Freitas, D., Meyer, J., Davis, L., Frometa, J., and Composto, R. (2019). Mapping data acquisition and processing summary report: EX-19-06, 2019 Southeastern U.S. deep-sea exploration (mapping). Office of Ocean Exploration and Research, Office of Oceanic & Atmospheric Research, NOAA, Silver Spring, MD 20910, 25p., doi.org/10.25923/7b86-jb66

Sowers D (2020) Utilizing Extended Continental Shelf (ECS) and Ocean Exploration Mapping Data for Standardized Marine Ecological Classification of the U.S. Atlantic Margin. Ph.D. Dissertation, University of New Hampshire, Durham, 150 pp.

White, M.P., Farrington, S., Galvez, K., Hoy, S., Newman, M., and Rabenold, C. (2019). Cruise Report: EX1907, Southeastern U.S. Deep-sea Exploration (Mapping & ROV). Office of Ocean Exploration and Research, Office of Oceanic and Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Cruise Rep. 19-07, 46 p. doi.org/10.25923/h510-x193

Images, maps, graphs, other key figures:

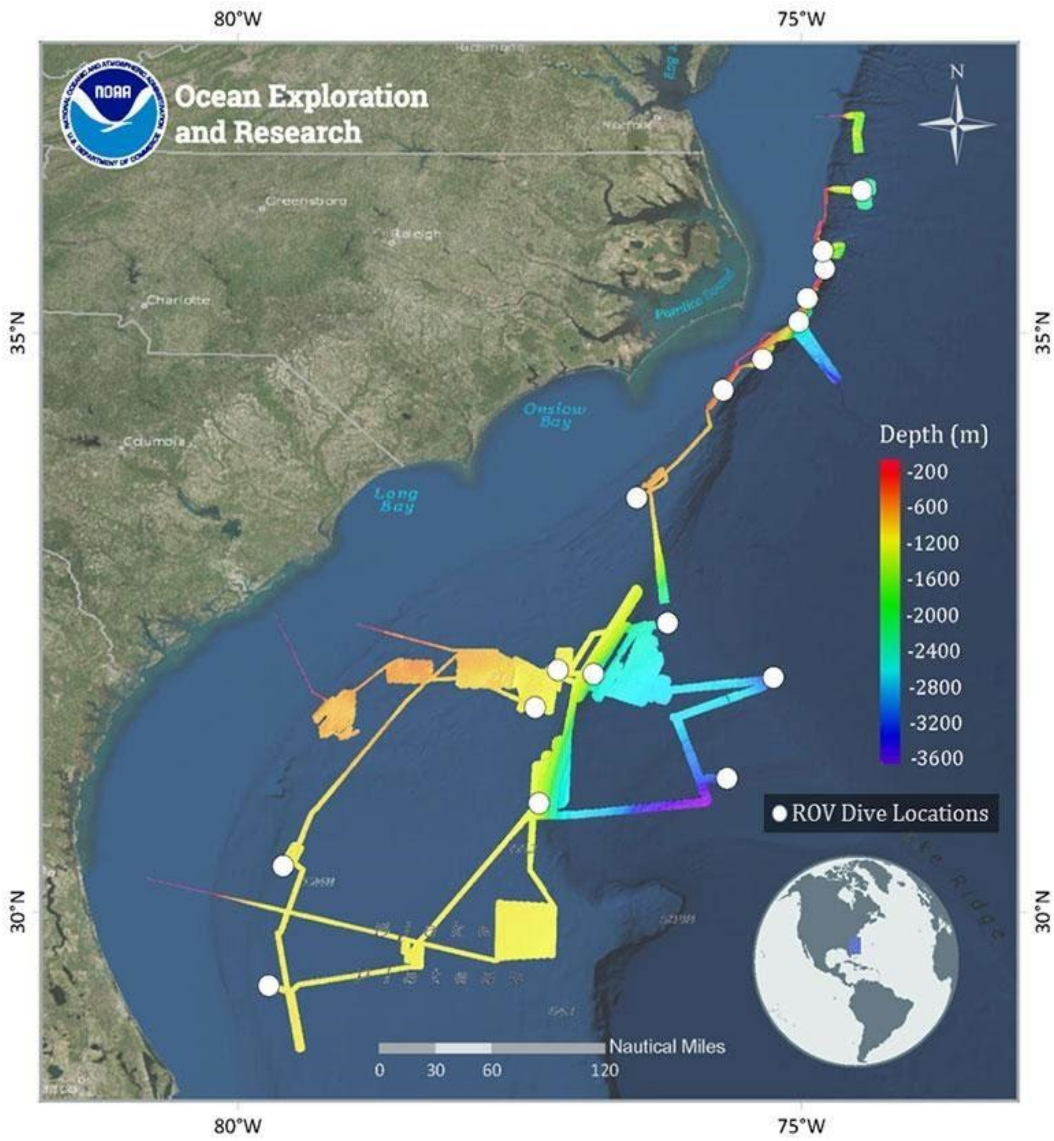


Figure 22. Cruise track with ROV dive locations and multibeam bathymetry for EX1805 and EX1806. Map: *NOAA OER*.

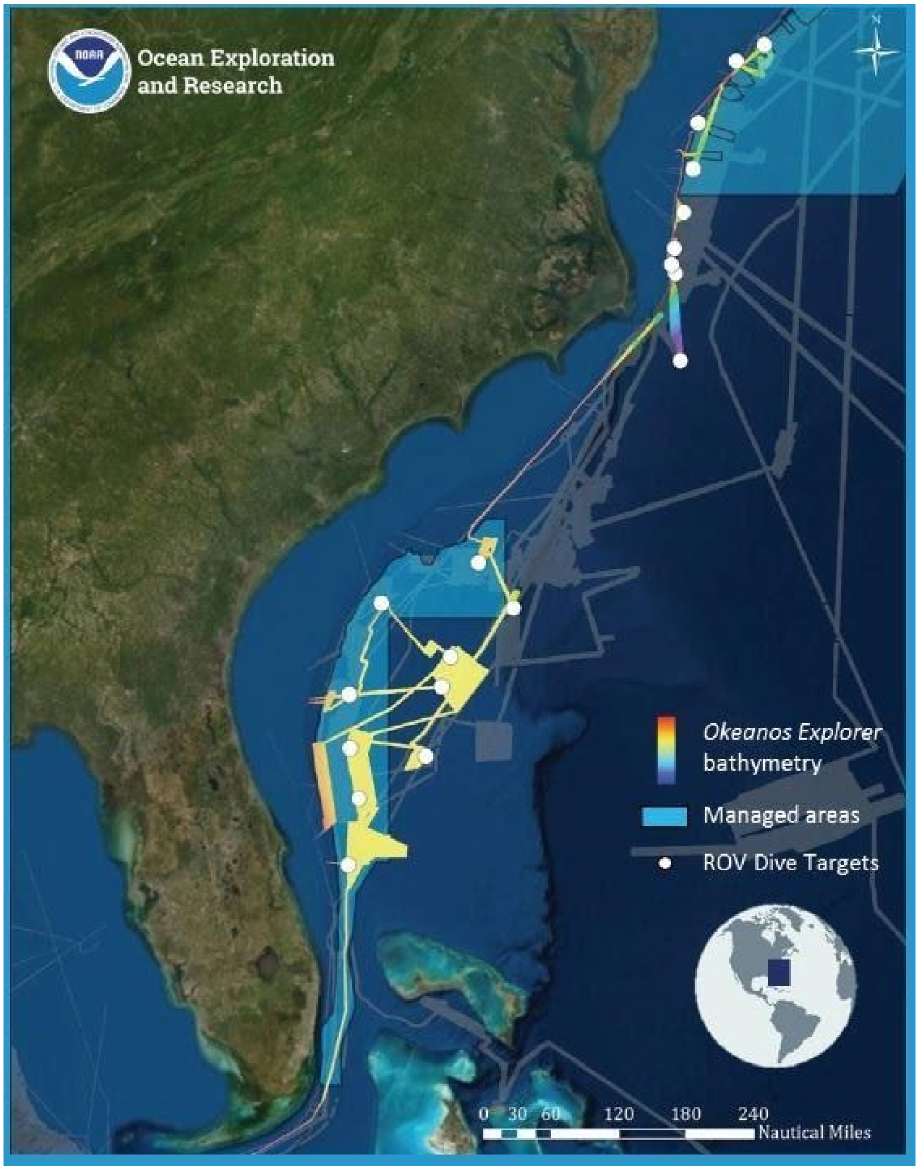


Figure 23. Cruise track with ROV dive locations and multibeam bathymetry for EX1903 shown with past data collected by OER from 2011 to 2018. Map: *NOAA OER*.

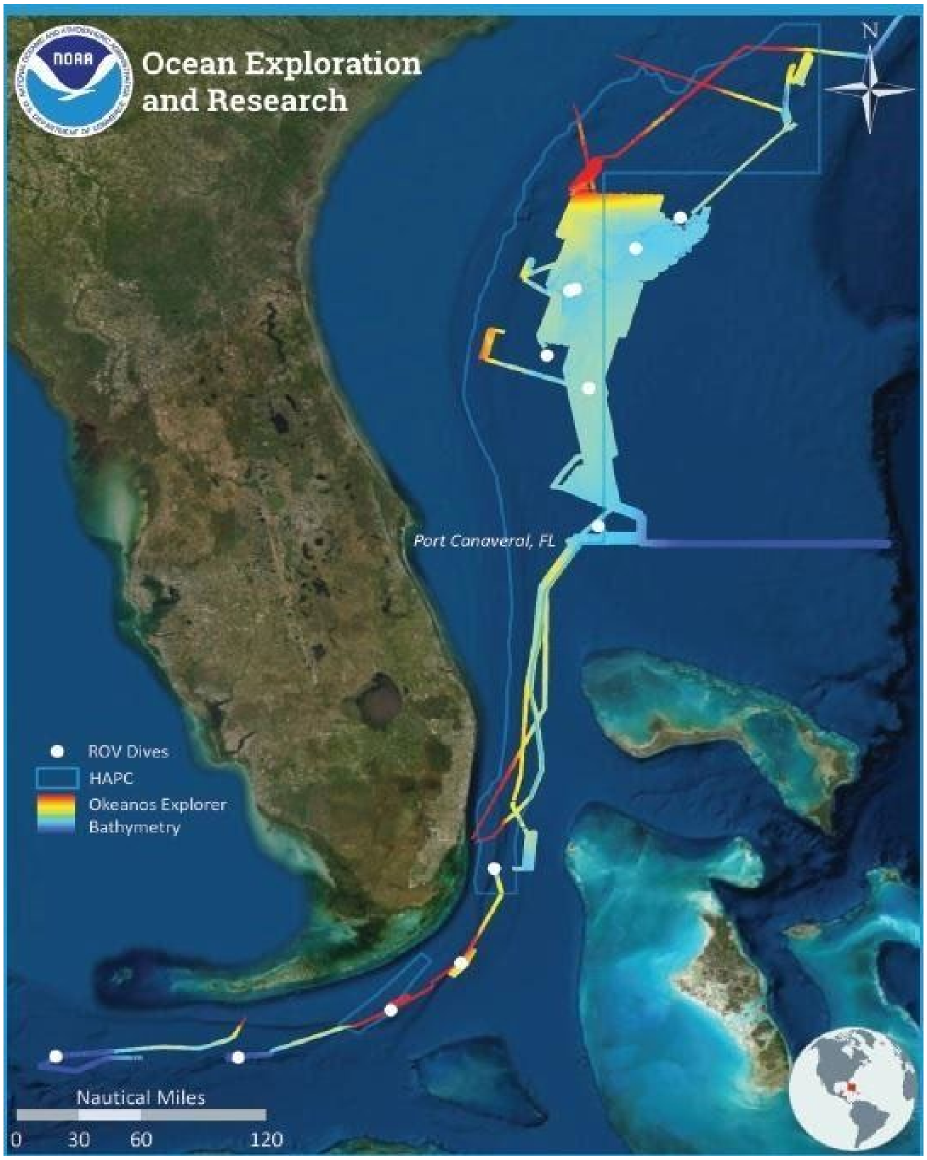


Figure 24. Cruise tracks with ROV dive locations and multibeam bathymetry for EX1906 and EX1907. Map: *NOAA OER*.

3.3.3 South Atlantic Council Deepwater Marine Protected Areas (MPAs): Characterization of Benthic Habitat and Biota

Background and Objectives:

In February 2009, the South Atlantic FMC implemented eight Type II MPAs between Cape Hatteras, North Carolina and the Florida Keys to protect seven species of the deepwater snapper-grouper complex. The closures, however, are expected to provide ecosystem-level benefits to the entire complex as well as protect the shelf-edge reef habitat they use. Bottom-tending fishing gear has been shown to have deleterious effects upon reefs (Fossa et al., 2002; Reed et al., 2007) and is now prohibited in the MPAs. As such, decisions to create future area closures will be based upon the efficacy of these areas and the lessons learned during their implementation. This project will benefit coral reef ecosystems directly by improving our understanding of the impact of fishing activities on both fish and invertebrate species.

The primary goal of this project is to gather additional data on habitat and fish assemblages in the South Atlantic MPAs as part of a long-term sampling program to document changes in these areas before and after implementation of fishing restrictions. Ultimately, the primary benefits of these data are to characterize and document the habitat, benthic and fish communities within the shelf-edge MPAs along the southeastern U.S. from North Carolina to south Florida. These data may then be compared to previous and future surveys and to areas adjacent to the protected areas to better understand the long-term health and status of these important deepwater coral and sponge ecosystems.

Approach:

ROV dives were conducted inside and outside each MPA using the UNCW Undersea Vehicle Program's ROV *Mohawk*. ROV transect locations were selected from multibeam mapping conducted on prior cruises with a concentration on repeating previous dives for comparison purposes. The resolution of the map products ranged from 0.2 to 26 m and extent of coverage was approximately 4,000 sq km. Average dive length was 1129 m (range 530 m to 2558 m) and each was oriented to allow coverage of the inshore, offshore and top of each target area. Each dive consisted of numerous transects which were delineated by similar habitat types. Transect lengths ranged from 50 to 500 m and approximate ROV speed over ground was 0.5 knots. Video transects were used for analysis of the fish populations. Digital still images taken perpendicular to the bottom approximately every two minutes throughout the dives were used to determine relative percent cover of benthic biota and habitat types. Both forward-looking video and forward- and down-looking still imagery incorporated paired lasers to allow measurements of targets. A collection skid on the ROV was used to collect vouchers of benthic macrobiota for museum collections, taxonomic identification, genetic analysis, and coral health studies. Temperature and depth (pressure) profiles were collected with a Sea-Bird 39 Temperature Recorder attached to the ROV for each dive.

Significant Results to Date:

Between May 12 and 24, 2018, 29 dives were conducted covering 26.8 km in the depth range of 44–266 m (Figure 25).

Macrobiota Results:

Twenty-five specimens were collected including 20 *Swiftia exserta* for genetic analysis. 176 taxa of benthic macrobiota were observed and used for percent cover analyses (Figure 26). Porifera were the dominant benthic macrobiota. Of the reef sites, the greatest cover of benthic macrobiota occurred outside Edisto MPA and inside Northern South Carolina MPA. Overall, sponges had the greatest average cover (6.31%), followed by macro algae (5.07%), black corals (2.66%), gorgonian octocorals (1.65%), and scleractinian corals (0.28%). Scleractinian corals were most common outside the North Florida MPA (0.41%), and Edisto sites (inside MPA-0.52%, outside-0.41%). Gorgonians had the greatest cover at Edisto (8.03% outside MPA) and at the Northern South Carolina MPA –deeper, iceberg scar sites (5.39%). Black corals were most common at the North Florida MPA sites (inside-8.88%; outside-5.80%), followed by Edisto MPA (2.17%), and the Georgia sites (1.95%). Sponges were also most common at Edisto (outside-11.59%, inside-8.62%) and North Florida (outside-9.77%, inside-9.30%). Macro algae were greatest at Northern South Carolina MPA-reef (inside-33.02%, outside-6.80%) and Edisto (outside-9.38%, inside-5.45%).

Octocoral Populations within the Shelf-Edge MPAs:

Of interest to the Deep Sea Coral Research and Technology Program is mapping the distribution of both scleractinian corals and gorgonian octocorals in U.S. waters. Our previous surveys of the shelf-edge MPAs discovered some very dense populations of the gorgonian octocoral *Swiftia exserta*, especially around Edisto MPA and the Snowy Wreck MPA reef sites. This orange or yellow sea fan, that grows to 1-2 ft in height, is common on these mesophotic reef sites and provides habitat structure for other invertebrates and fish (Figure 27). Approximate counts of

Swiftia colonies were made during the dives at sites with dense *Swiftia* populations (Table 3). Seven sites had *Swiftia*; the outside Edisto MPA site had a count of 1,736 colonies during the dive, whereas three dives inside Edisto MPA had 83, 21, and 9 colonies.

Fish Results:

In total, 138 species were observed, including four of the seven target species: blueline tilefish (*Caulolatilus microps*), yellowedge grouper (*Hyporthodus flavolimbatus*), snowy grouper (*Hyporthodus niveatus*), and warsaw grouper (*Hyporthodus nigritus*). A large school of approximately 50 red snapper (*Lutjanus campechanus*) were observed outside the Georgia MPA and smaller schools were seen inside the North Florida MPA. Small schools of grey snapper (*Lutjanus griseus*) were observed inside and outside the North Florida MPA as well as inside the Edisto MPA. A total of 1697 lionfish (*Pterois volitans*) were recorded on the 2018 dives. This year had the most lionfish on a single dive (n = 646) since the inception of this project in 2004. This suggested a density of 245.63 lionfish per 1000 m^2 for that dive, which was conducted inside the Edisto MPA. Depth, habitat type, and geographic region contributed more to fish assemblage composition than did MPA status (inside vs outside). However, densities of most species of the snapper-grouper complex were generally higher inside the MPAs than outside.

Points of Contact:

Stacey Harter (stacey.harter@noaa.gov) and Andy David (andy.david@noaa.gov), NOAA Fisheries' Southeast Fisheries Science Center, Panama City, FL.

John Reed (jreed12@fau.edu) and Stephanie Farrington (sfarrington@fau.edu), Cooperative Institute of Ocean Research, Exploration and Technology Harbor Branch Oceanographic Institute, Florida Atlantic University, Fort Pierce, FL.

References and document links:

Fossa, J.H., P.B. Mortensen, and D.M. Furevik. 2002. The deepwater coral *Lophelia pertusa* in Norwegian waters: distribution and fishery impacts.

Reed, J.K., C.C. Koenig, and A.N. Shepard. 2007. Impacts of bottom trawling on a deepwater *Oculina* coral ecosystem off Florida. Bull. Mar. Sci. 81(3): 481-496.

Publications from project:

Harter, Stacey, John Reed, Stephanie Farrington, Felicia Drummond, and Andy David. 2019. South Atlantic MPAs and Oculina Bank HAPC: Characterization of benthic habitat and biota. NOAA Ship *Pisces* Cruise 18-02. NOAA CIOERT Cruise Report, 318 pp. Harbor Branch Oceanographic Technical Report Number 188.

Harter, Stacey, Andy David and John Reed 2019. South Atlantic Oculina Experimental Closed Area and Deep-Water Marine Protected Areas: Characterization of Benthic Habitat and Fauna

Images, maps, graphs, other key figures:

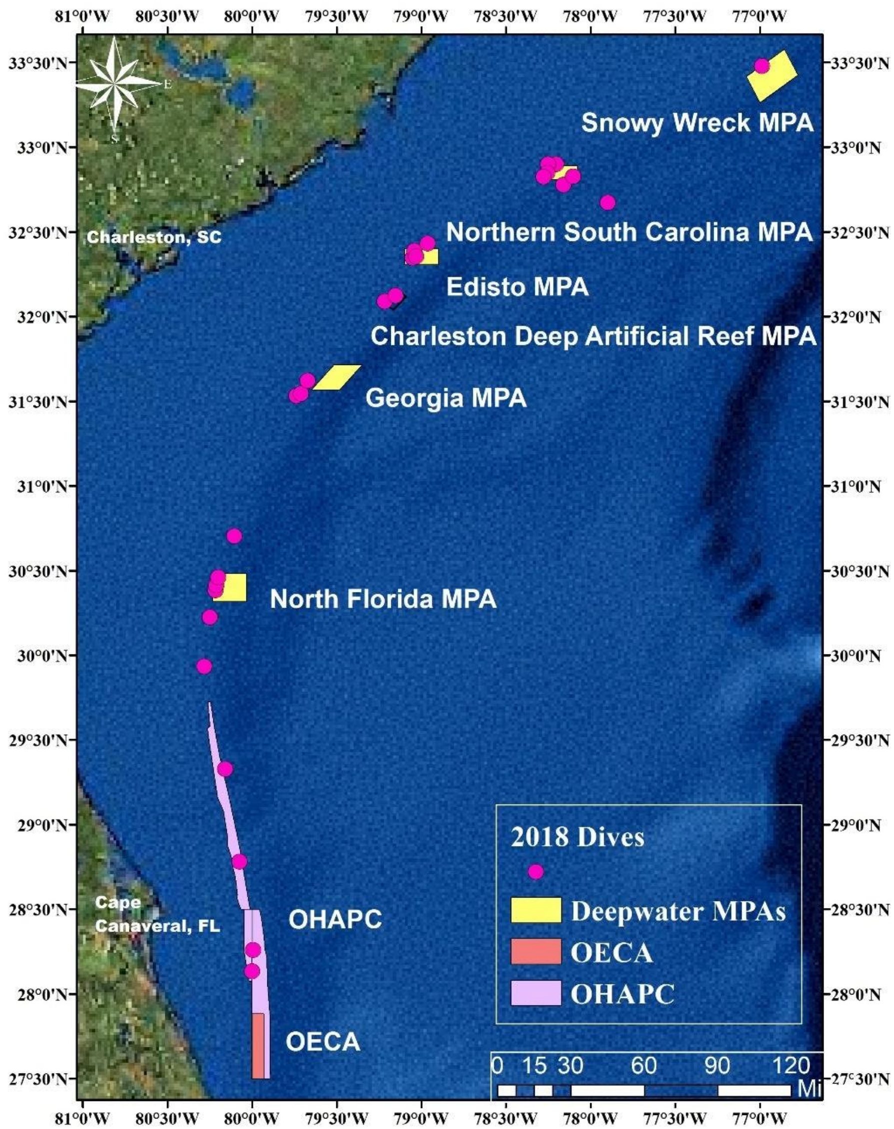


Figure 25. ROV *Mohawk* dives completed during NOAA Ship *Pisces* cruise 18-02 from May 12-24, 2018. MPA = marine protected area; OECA = Oculina Experimental Closed Area (closed to bottom contact fishing in 1984); OHAPC = Oculina Bank Habitat Area of Particular Concern (closed to bottom contact fishing in 2015).

Table 3. Counts of *Swiftia exserta* gorgonians from video analysis of ROV dives during NOAA Ship *Pisces* cruise 18-02.

	Inside North FL MPA	Inside Snowy Wreck MPA	Inside Edisto MPA	Outside Edisto MPA	Inside North SC MPA	Total
Swiftia exserta	1	2	113	1736	43	1895

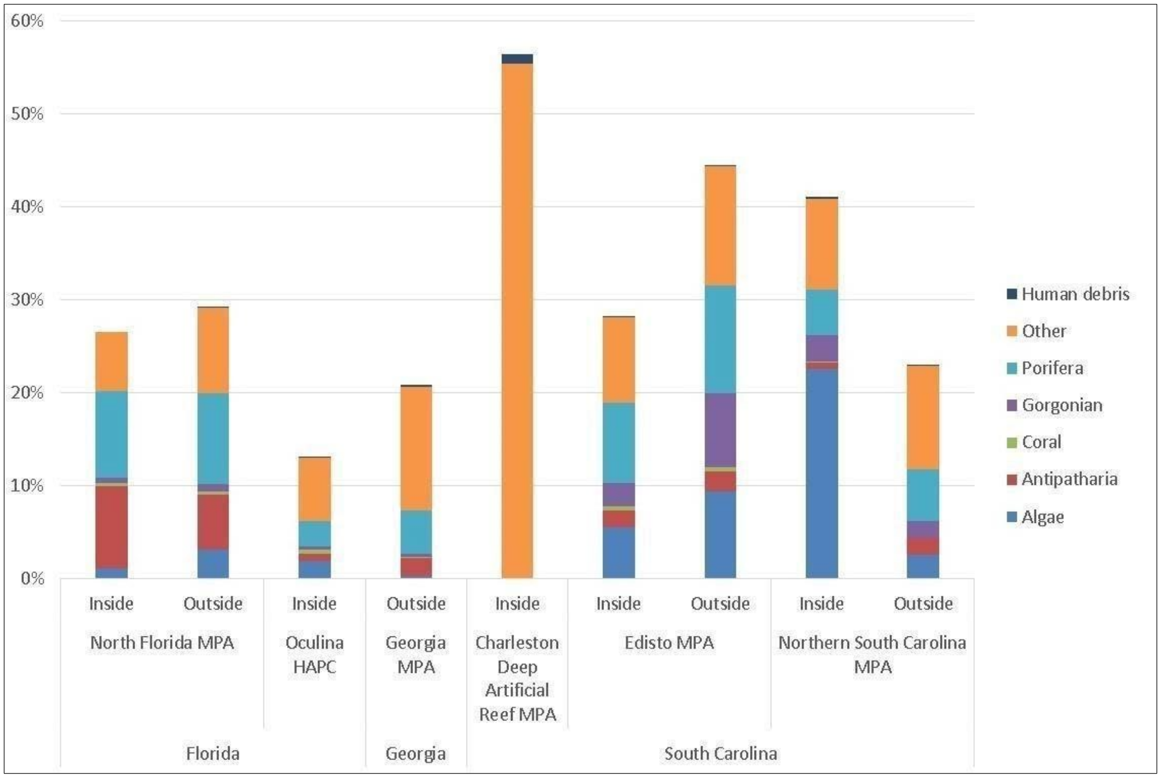


Figure 26. Percent cover of major benthic macrobiota and human debris listed by MPA status and region from Coral Point Count analysis of ROV transects during NOAA Ship *Pisces* cruise 18-02, May 12-24, 2018. "Other" includes Arthropoda, Bryozoa, Chordata, Echinodermata, and Mollusca.

Figure 27. Fields of the octocoral *Swiftia exserta* are shown here in the foreground, outside the Edisto Marine Protected Area offshore South Carolina, with polyps exserted (pale colonies) and retracted (orange colonies).

3.4 SEDCI Fieldwork in the U.S. Caribbean

Of the three SEDCI regions, the U.S. Caribbean is the smallest, but least explored and least understood. In November 2015, the Caribbean FMC identified specific needs at a NOAA led planning workshop for SEDCI (Schull et al., 2016). At that time, they expressed a need for Caribbean habitat suitability models for deep-sea corals, bilingual telepresence exploration, and studies on the deepwater snapper/grouper fishery. SEDCI efforts in the U.S. Caribbean centered on; (1) building a GIS database of past deep-sea explorations of the region, (2) a fieldwork project with deepwater snapper and grouper fishermen, (3) video analysis of historical submersible surveys, and (4) new ROV video footage and mapping off the coast of Puerto Rico.

References and document links:

Schull J, Etnoyer PJ & Wagner D (2016) NOAA Deep Sea Coral Research and Technology Program Southeast Initiative Priority Scoping Workshop Report, November 18-20, St. Petersburg, Florida. NOAA Technical Memorandum. NMFS-SEFSC-695, 59pp.

Images, maps, graphs, other key figures:

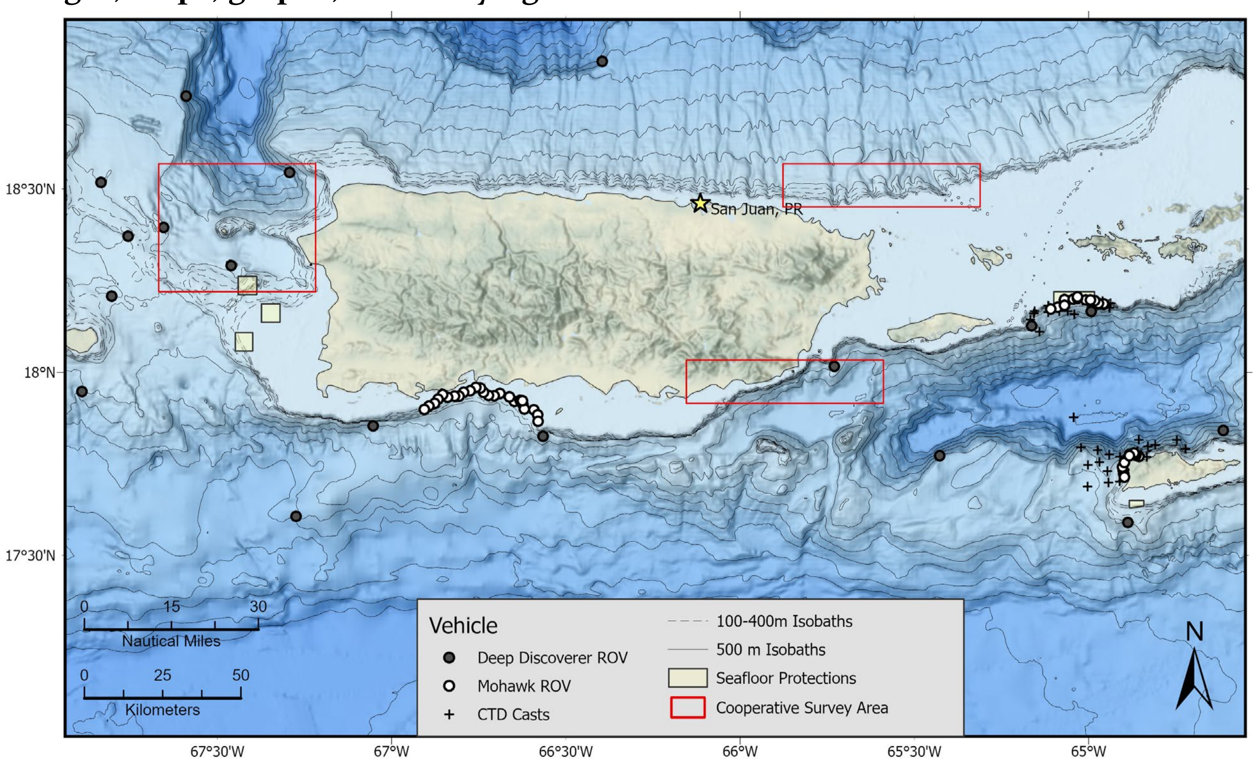


Figure 28. SEDCI ROV dives and CTD casts in the U.S. Caribbean from 2016-2019. Red squares depict the areas for the habitat classification project summarized in Section 3.4.3. One ROV dive was outside the map extent, to the northeast.

3.4.1 NOAA Ship *Nancy Foster* Cruises in the U.S. Caribbean

Background and Objectives:

The last two years of SEDCI fieldwork in 2018 and 2019 were focused on the Caribbean region. As part of this focus, two cruises were co-funded to augment an ongoing, multi-year scientific research mission in the Caribbean aboard NOAA Ship *Nancy Foster*, in partnership with NOAA's Coral Reef Conservation Program. The purpose of these cruises was to collect swath bathymetry, acoustic backscatter, optical validation using an ROV, fishery acoustics, and coral samples within coastal waters of Puerto Rico and the U.S. Virgin Islands (Battista et al., 2020).

SEDCI contributed staff time and expertise from coral biologists at NCCOS MSE, as well as funding for the use of ROV *Mohawk* from University of North Carolina Wilmington. Four days were dedicated to coral sampling aboard these cruises, and one day was dedicated to the deployment of temperature loggers, while other days adopted new photographic techniques to document the corals using forward looking cameras.

Approach:

Field work aboard *Nancy Foster* was generally divided into daytime and nighttime operations. Daytime operations were conducted while the ROV collected samples and images to characterize seafloor features. At night, scientists operated a high-resolution multibeam echosounder, and also collected fishery acoustic data at depths approximately 11 to 3066 m. A forward-looking camera was added to the ROV package in 2018 and a manipulator arm was added in 2019. The manipulator arm was used for specimen collections to serve as vouchers for benthic corals observed in visual surveys. Video and still images were used to characterize habitat and biology, and ground-truth mapping data.

Significant Results to Date:

During the 2018 cruise, 350 sq km, at depths from 11-1388 m, were mapped with multibeam sonar off the south coast of Puerto Rico (Figure 29). In 2019 over 460 sq km were mapped in St. Croix and St. Thomas at depths from 11-324 m (Figure 30). The northwest shelf of St. Croix was previously unmapped and unexplored.

Over 946 km of fish acoustics surveys from 2018 were analyzed to determine distribution and size of fish. In 2019, during 853 km of acoustic surveys, fish schools were detected on the shelf edge off St. Croix. Deep scattering layers of zooplankton and small pelagic fish were observed at various depths on the shelf edge off St. Thomas and vertical migration was observed at dawn and dusk.

ROV surveys from both cruises traversed 21 km, collecting high definition video for benthic habitat characterization. Rich assemblies of deep and mesophotic coral communities were documented and explored. In 2018, off the coast of Puerto Rico, coral communities varied distinctly by depth strata with the highest densities at shallow depths, 15 to 30 m. Several coral species, such as *Swiftia exserta,* were observed on steep wall features between 40 and 100 m. At deeper strata, aggregations of black coral and octocoral sea fans were observed atop rock walls. During 2019, the team collected 41 samples of octocoral and black corals to support habitat models, contribute to population connectivity studies, and develop new field guides.

Point of Contact:

Tim Battista (Tim.Battista@noaa.gov), NOAA NCCOS MSE

Publications from project:

Battista. T., Shuler, A., Taylor, C., Kraus, J., Bassett, R., Salgado, E., Etnoyer, P. (2020). Cruise Report for NOAA Ship *Nancy Foster* NF-19-01: Mapping Essential Fish Habitat in the US Caribbean to Inform MPA Management (2019). NOAA Technical Memorandum NOS NCCOS 274. Silver Spring, MD. 102 pp.

Images, maps, graphs, other key figures:

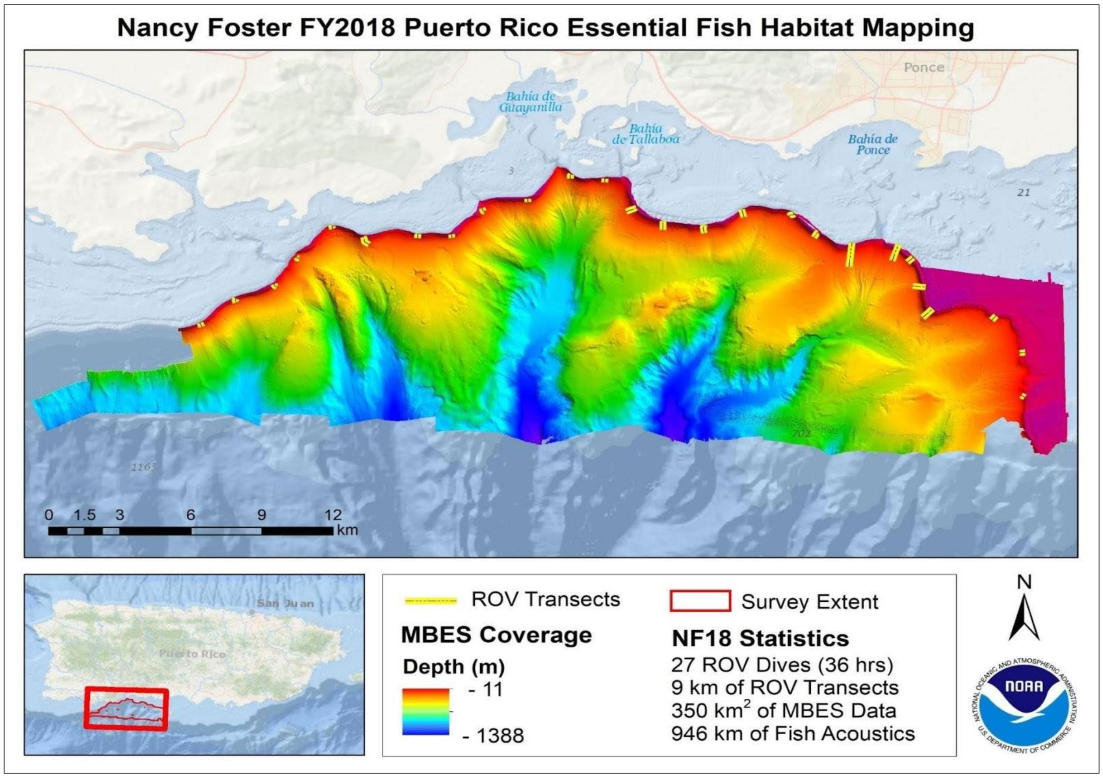


Figure 29. Map showing ROV dives and bathymetry data collected in 2018 off the southern coast of Puerto Rico.

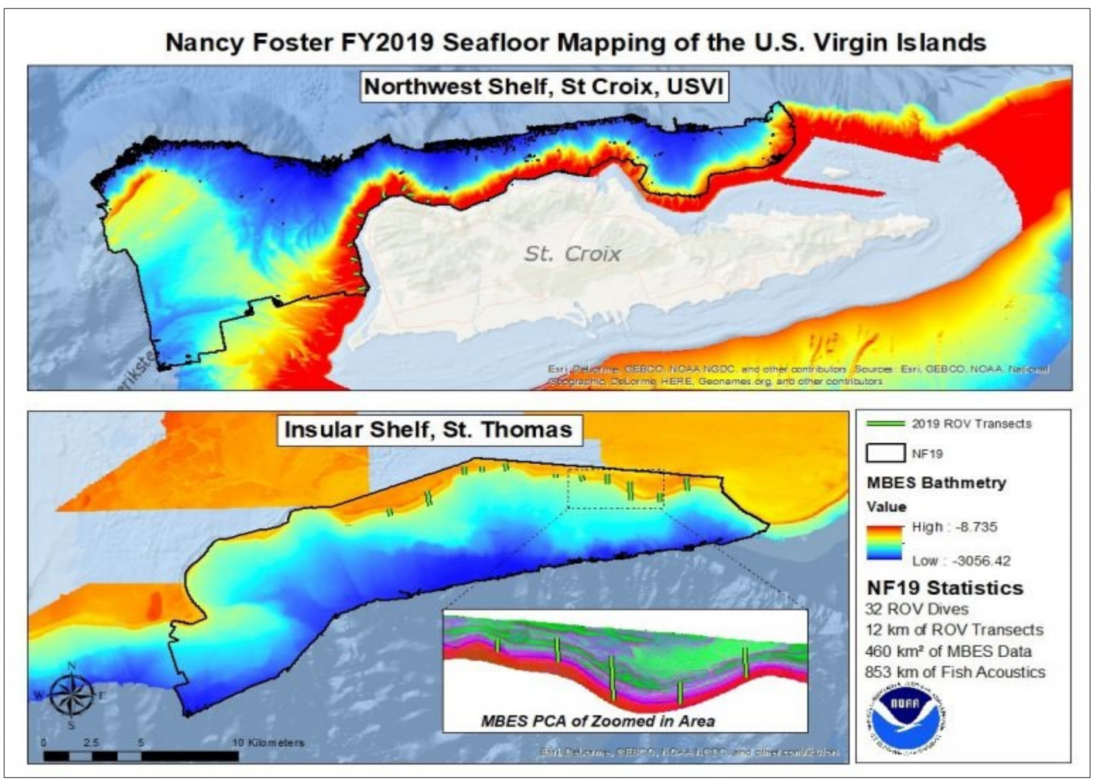


Figure 30. Map showing ROV dives and bathymetry data collected in 2019 off the coasts of St. Thomas and St. Croix.

3.4.2 NOAA Ship *Okeanos Explorer* Expedition: Océano Profundo

Background and Objectives:

Between October 30 and November 20, 2018, OER and partners conducted a telepresence-enabled expedition on NOAA Ship *Okeanos Explorer* (EX1811) to collect critical baseline information about unknown and poorly understood deepwater areas surrounding Puerto Rico and the U.S. Virgin Islands. The EX1811 expedition was entitled "Océano Profundo" and was part of the ASPIRE campaign. It was co-led by SEDCI Research Coordinator, Daniel Wagner. The goal of the expedition was to use ROV dives in combination with mapping operations to increase our understanding of deep-sea ecosystems in this poorly studied region, and to provide a foundation of publicly accessible data to spur further exploration, research, and management activities.

Specific SEDCI-relevant objectives included:

- Acquire data on deepwater habitats to support science and management needs in Caribbean waters off Puerto Rico and the U.S. Virgin Islands
- Explore deepwater areas relevant to resource managers, such as MPAs, and other priority management areas
- Map, survey, and characterize the diversity and distribution of deep-sea benthic communities, particularly those found within deep-sea coral and sponge habitats, deepwater snapper and grouper habitats, and other vulnerable marine habitats
- Investigate biogeographic patterns and connectivity of deep-sea organisms for use in broader comparisons of deepwater habitats across the Atlantic Basin
- Collect high-resolution bathymetry and backscatter data in areas with no (or low-resolution) sonar data
- Acquire a foundation of ROV, sonar, and oceanographic data to better understand the characteristics of the water column and the pelagic fauna

Approach:

Using OER's dual-body ROV, *Deep Discoverer,* the expedition completed 19 dives ranging in depth from 250 to 5,000 m that explored a wide diversity of habitats and geological features, including deep-sea fish habitats, deep-sea coral and sponge communities, submarine canyons, and submarine landslides (Figure 31). Midwater explorations at depths ranging from 300-2,000 m were also conducted during two ROV dives to investigate the diversity and abundance of the largely unknown pelagic fauna of the region. Overall, hundreds of species were observed during ROV dive operations, including several potentially undescribed species and several range extensions. Throughout the expedition, 82 biological samples were collected (39 primary and 43 associated taxa), 19 of which represent either range expansions or potential new species. The remainder of the biological samples were collected to support studies on connectivity and biogeographic patterns across the Atlantic Ocean.

Significant Results to Date:

- Six high-density communities of deep-sea corals and sponges were documented during the expedition.
- Commercially important deepwater fish species were documented on six dives, including a sighting of the queen snapper (*Etelis oculatus*) at a record depth of 539 m.
- Other noteworthy ROV observations included a translucent egg case with a catshark embryo actively swimming inside, first-time documentation of several species of deep-sea urchins feeding, and documentation of three species of sea stars that are likely new to science.

- The expedition investigated diverse geological features, including two large submarine landslides, one of which is believed to have caused the large tsunami of 1918.
- Eight rock samples were collected for geochemical composition analyses and age-dating to increase our understanding of the geological context of this region.
- The expedition also included mapping operations using four different sonar systems (multibeam, split-beam, sub-bottom profiler and ADCP).
    - Over 14,959 sq km of seafloor were mapped over the course of the expedition, including areas around Mona Island, Saba Valley, and Engaño Canyon that had never before been mapped using high-resolution sonar
- A total of 63 scientists, managers, and students from 37 institutions in seven countries participated in the expedition as members of the science team through telepresence technology.

Points of Contact:

Caitlin Adams (caitlin.adams@noaa.gov), NOAA OER
Derek Sowers (derek.sowers@noaa.gov), NOAA OER

References and document links:

All 14.2 TB of data collected during the expedition, including video and environmental data collected on every ROV dive, mapping data, oceanographic and meteorological data, have been made publicly available through national archives. Data disposition is described in detail in the cruise report below, and can be accessed directly through the OER Digital Atlas (https://www.ncei.noaa.gov/maps/oer-digital-atlas/mapsOE.htm). Records of deep-sea corals and sponges observed with associated frame-grabs are available from the DSCRTP website (https://deepseacoraldata.noaa.gov/).

Auscavitch, Steven; Wagner, Daniel; Williams, Stacey (2019). Oceanographic data collected during the EX1811 Puerto Rico and U.S. Virgin Islands (ROV & Mapping) expedition on NOAA Ship OKEANOS EXPLORER in the Gulf of Mexico from 2018-10-30 to 2018-11-20 (NCEI Accession 0183293). NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/k2e7-rw29.

Highlight images, videos, educational materials, and descriptions of the accomplishments of the expedition are available via the expedition website (https://ocean*Explorer*.noaa.gov/*Okeanos*/explorations/ex1811/welcome.html).

Publications from project:

Wagner D, Sowers D, Williams SM, Auscavitch S, Blaney D & Cromwell M (2018). EX1811 Expedition Report - Océano Profundo 2018: Exploring Deep-Sea Habitats off Puerto Rico and the U.S. Virgin Islands. Office of Ocean Exploration and Research, Office of Oceanic & Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Report EX1811, 171 pp. doi: 10.25923/wc2n-qg29

Images, maps, graphs, other key figures:

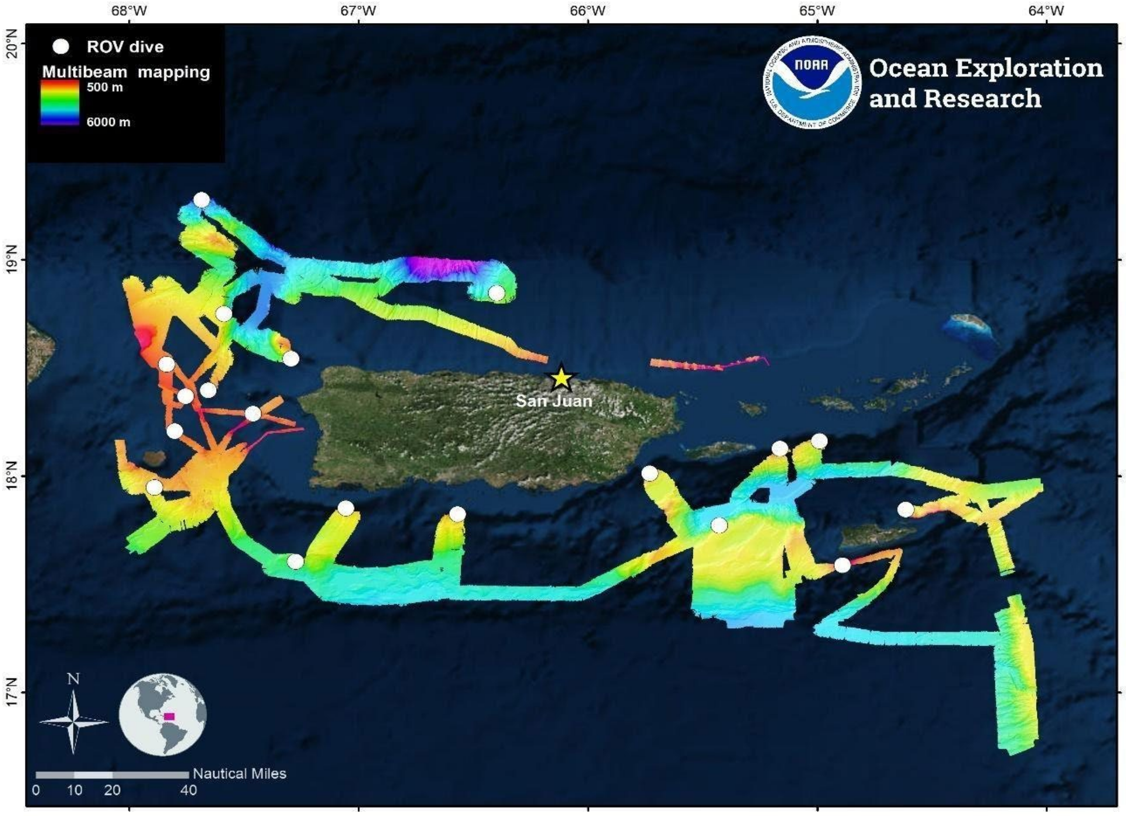


Figure 31. Cruise track with ROV dive locations and multibeam bathymetry for EX1811. *NOAA OER.*

3.4.3 Habitat Classification in Puerto Rico's Deep Drop Fishery and Habitat Use by Queen Snapper, *Etelis oculatus*

Background and Objectives:

The narrow continental shelf surrounding the island of Puerto Rico places deepwater habitats in relatively close proximity to shore, allowing fishing for mesophotic and deep species from small vessels with limited range. Queen snapper (*Etelis oculatus*) is of interest from an ecological and management perspective as it is a targeted component of the deepwater snapper-grouper complex throughout Puerto Rico and the Caribbean, yet little is known of its life history, fine-scale distribution patterns, and habitat use. The Caribbean FMC ranked investigations into this fishery, particularly the habitats it targets, at the highest priority level for deepwater research in their region.

The objectives of this project were to develop a fishery independent survey of the deepwater queen snapper fishery in waters offshore of Puerto Rico from depths of 100-500 m, using both hook and line fishing and a tethered camera system. The targeted depth range for this project encompasses the known range of queen snapper (Gobert et al., 2005). The imagery collected will be used to document and assess potential linkages between deepwater fish assemblages and habitat/invertebrates, specifically describing habitat use by queen snapper. Additionally, biological samples of queen snapper and blackfin snapper (*Lutjanus buccanella*) will be used in two ongoing studies estimating growth, longevity and natural mortality.

Approach:

A fishery-independent survey was developed and conducted from 2017-2020 to explore habitat associations of deepwater snappers and document deepwater coral ecosystems off the west, northeast, and southeast coast of Puerto Rico. Survey sites were selected using a stratified random statistical sampling design, from locations considered to have a high probability of containing essential fish habitats for deepwater snapper. This was determined using bathymetric maps recently produced by NOAA NCCOS's Marine Spatial Ecology Division. Nine sampling sites were selected in each 50 m depth bin throughout that range. The selected survey sites are center points of 500 x 500 m boxes within a grid system.

Samples were collected using vertical longlines and electric reels, with an attached weight and baited hooks – the traditional deepwater snapper fishing method for anglers in Puerto Rico. Fishing equipment was standardized throughout all three regions, including hook type and size, number of hooks per line, bait types, and soak time. The sampling of any individual site consisted of the deployment of one vertical hook and line with twelve baited hooks, soaked for twenty minutes, followed directly by the deployment of a remote video camera, three baited hooks, and soaked for five minutes. The remote video camera is comprised of a GoPro (HERO4, GoPro, Inc., San Mateo, CA) in a small, pressure tested housing (GG HousingGoPro4 300 Extended, Golem Gear, Inc., Brooksville FL), and an LED video light (Lumen Subsea Light, Blue Robotics, Inc., Torrance, CA; EBL1200D, Sartek Industries, Inc., Setauket, NY), both secured to a small plastic panel attached to the fishing line with two gangions.

Habitat and benthos were documented at 471 sites. All fish caught on hook and line were identified to the lowest taxonomic level possible, and length measurements were recorded by an observer. Biological samples (otoliths and gonads) were taken from queen snapper and blackfin snapper by the observer once a trip was completed, in addition to basic demographic data (e.g., length, weight, sex). The commercial fishermen were encouraged to retain the fish they would normally keep, within season, once samples were taken.

Significant Results to Date:

The survey resulted in 471 videos documenting habitat and deepwater invertebrates (Figure 32). This is the first time that a combination of tethered video and hook and line sampling was used by fishermen in Puerto Rico to document habitat, fish diversity, and benthic invertebrates of poorly studied deepwater reefs. Video analysis is ongoing. All videos were reviewed for fish and invertebrate identification, species presence or absence, and habitat classification.

Coral point count analysis has been completed for the first year of sampling efforts. Preliminary results identified 77 fish species on video, 22 species caught on hook and line, and over 100 invertebrate (sessile and mobile) taxa. Several locations off the west coast exhibited high diversity of invertebrates, which could influence management decisions in the future (Figure 33). Preliminary analysis shows that the western region of Puerto Rico contained the most diverse and abundant coral and sponge communities, with twelve orders identified, followed closely by the southeast (n=9), and lastly the northeast (n=4). The taxa documented during the two year project yielded a total of 1,604 individual corals and sponges, made up of five classes (Figure 34). These data will be further explored to assist with describing habitat utilization and linkages between queen snapper and deepwater coral communities.

Biological samples collected from queen snapper and blackfin snapper are contributing to life history studies. In total, 114 queen snapper samples and ten blackfin snapper samples were collected. Otolith samples have been sectioned and are currently undergoing age estimation. Shark species caught as bycatch in this project were used in DNA barcoding to describe the diversity of sharks caught in Puerto Rico, a project being conducted by G. Franqui at the

Department of Marine Sciences, University of Puerto Rico, Mayagüez. Pictures were taken of the shark bycatch species for preliminary identification at sea, and a DNA sample was collected for processing.

The final products from this work will be published in a peer-reviewed journal.

Points of Contact:

Kate Overly (katherine.overly@noaa.gov), RTI, in support of NOAA Fisheries
Andrew David (andy.david@noaa.gov), NOAA Fisheries

References and document links:

Gobert, B., Guillou, A., Murray, P., Berthou, P., Oqueli Turcios, M.D., Lopez, E., Lorance, P., Huet, J., Diaz, N., Gervain, P. 2005. Biology of queen snapper (*Etelis oculatus*: Lutjanidae) in the Caribbean. Fish. Bull. 103:417-425.

Publications from project:

Overly, K.E. V.L. Lecours. 2021 (in prep). Mapping Queen Snapper (*Etelis oculatus*) Suitable Habitat in Puerto Rico Using Ensemble Species Distribution Modeling.

Images, maps, graphs, other key figures:

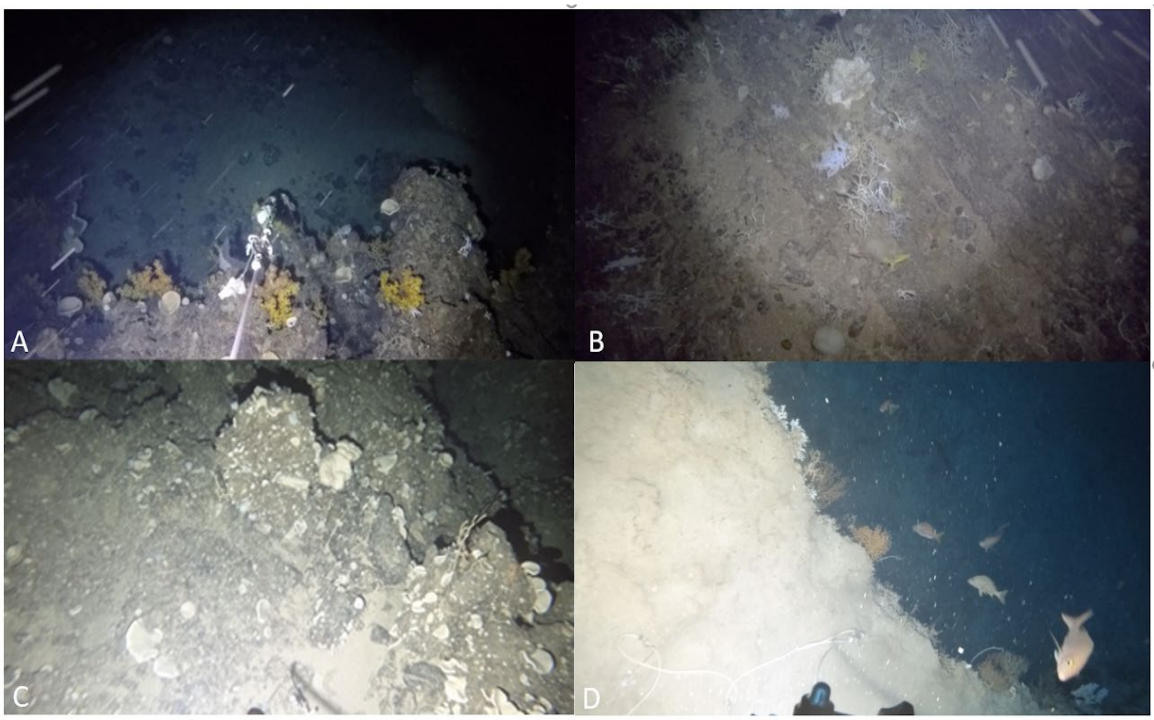


Figure 32. Photos from deepwater coral and sponge communities off the west coast of Puerto Rico at depths of A) 428 m, B) 251 m, C) 316 m, and D) 190 m.

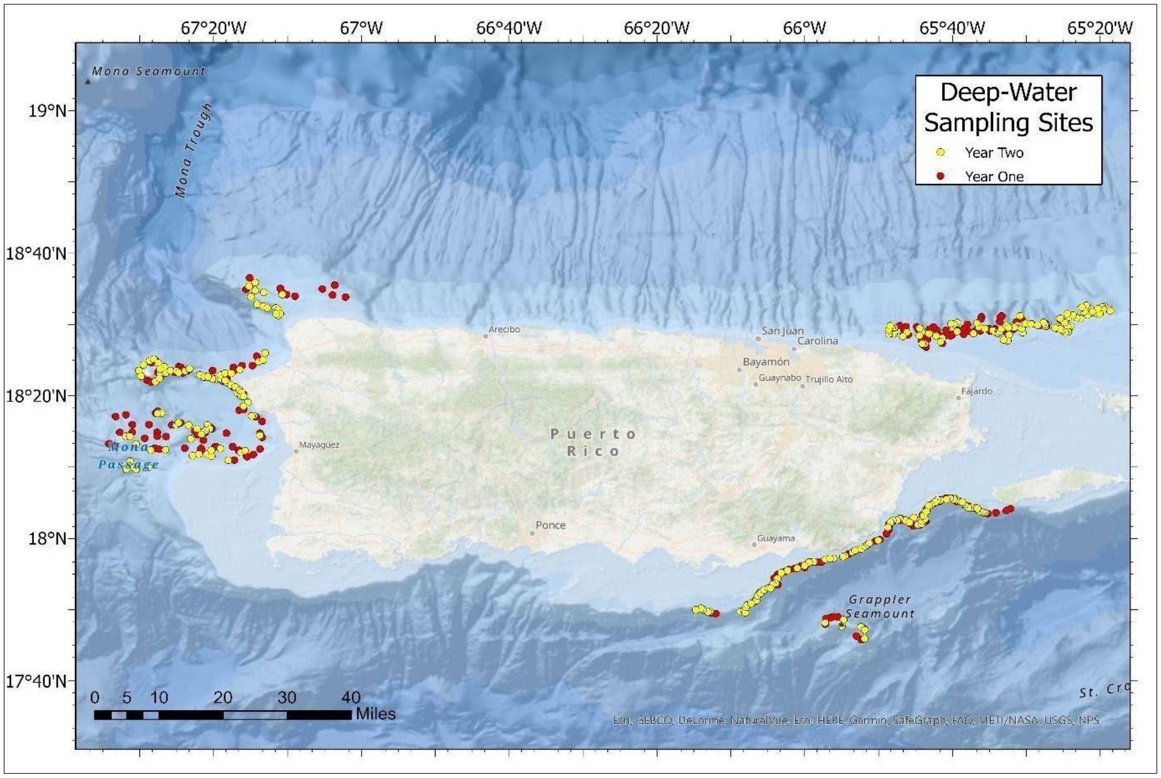


Figure 33. Maps of all survey sites sampled in two years with remote video camera and hook and line fishing along the western, northeastern, and southeastern coasts of Puerto Rico.

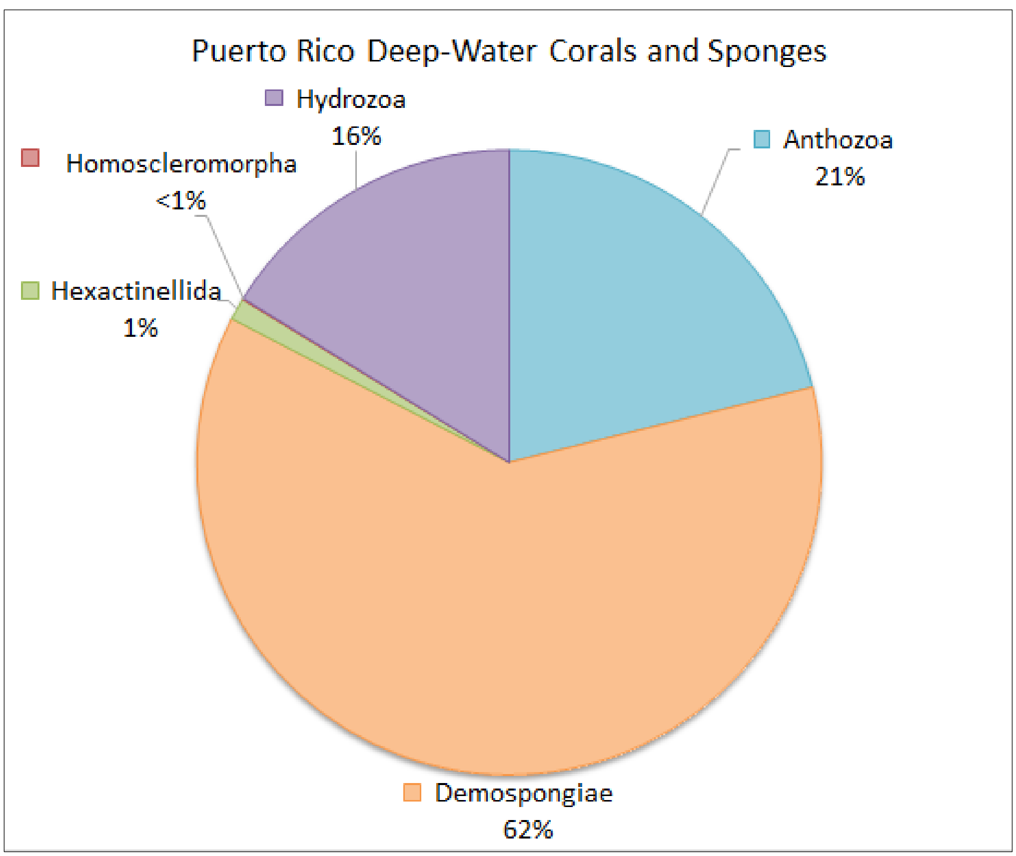


Figure 34. Proportion of deepwater invertebrate classes identified within the three regions surveyed in Puerto Rico, documenting five orders of sessile invertebrates totaling 1,604 individuals.

4. Small Projects

In addition to research expeditions and other fieldwork, SEDCI created products and performed research to enhance knowledge and resources for the Southeast deep-sea coral and sponge community. These small projects ranged from new photo identification guides and online GIS resources, to deployment of sensors for environmental monitoring.

4.1 Southeast Deep-Sea Coral Initiative Digital Atlas

Background and Objectives:

Planning for ocean exploration and management of the deep sea is a challenging endeavor because it requires planners to combine disparate efforts to map, describe, and monitor ecosystems across a broad regional geographic range of the Southeast U.S., which extends 200 km offshore. In order to address this challenge and support the SEDCI, a GIS geodatabase was compiled to illustrate the work that had been done in the region. The compilation of knowledge contained in this geodatabase was instrumental in planning for SEDCI, so that new field surveys would build upon and not duplicate previous work.

The objective was to build an online geodatabase that incorporates a wide variety of information useful for planning deep-sea surveys. The data layers include submersible/ROV dive locations, boundaries of existing and proposed marine managed areas, ship tracks showing the footprint of mapped areas, deep-sea coral and sponge observations, and habitat suitability models. While the initial audience for this tool was internal (SEDCI staff), the geodatabase is publicly accessible via ArcGIS Online for use outside of the SEDCI effort. The website will remain in perpetuity, and updated as needed.

Approach:

The data in the geodatabase were derived from many sources. Submersible and ROV dive sites were from lists curated by: Woods Hole Oceanographic Institution for HOV *Alvin* and ROV *Jason*; University of North Carolina Wilmington for the ROVs *Mohawk*, *Phantom,* and *Kraken*; Florida Atlantic University's Harbor Branch Oceanographic Institute for HOVs *Johnson Sea Link* I and II, among others. The General Bathymetric Chart of the Oceans (GEBCO) was used as the basis of the undersea feature names layer. Records of deep-sea corals and sponges were served through NOAA's National Database of Deep-Sea Corals and updated quarterly. Boundaries delineating marine managed areas (i.e., MPAs), proposed expansions of protected areas, HAPCs, and Essential Fish Habitat) were obtained from a variety of sources including the NOAA MPA Center; the regional fishery management councils; and Flower Garden Banks National Marine Sanctuary.

Habitat suitability models for the Gulf of Mexico and Southeast U.S. were developed by NCCOS's Marine Spatial Ecology Division. An inventory of mapping survey footprints was developed for all three areas of interest by synthesizing cruise metadata and bathymetry data from multiple sources, including the NOAA National Centers for Environmental Information Bathymetric Data Viewer and the U.S. Geological Survey Pacific Coastal and Marine Science Center. Locations of critical infrastructure for oil and gas (i.e., platforms and pipelines) were from BOEM. BOEM lease blocks are also available for the Gulf of Mexico region. Locations of major ports, shipping channels, and oil terminals, derived from the World Port Index, are also included in the atlas.

Significant Results to Date:

The data layers and inventories were collected over the course of two years in 2016 and 2017 and assembled into a beta version of the GIS geodatabase. The geodatabase formed the basis for the Southeast Deep Coral Initiative Digital Atlas, which went online to the public in October 2017. Improvements were made in 2019 based on feedback from reviewers, including enhanced symbology and updated data layers for submersible dives, deep-sea corals for all regions, and updates to proposed HAPCs in the Gulf of Mexico.

Point of Contact:

Dan Dorfman (dan.dorfman@noaa.gov), NOAA NCCOS MSE

Additional Collaborators:

Jacob Howell; Heidi Burkart; Katie Miller

References and document links:

[SEDCI Digital Atlas]

Images, maps, graphs, other key figures:

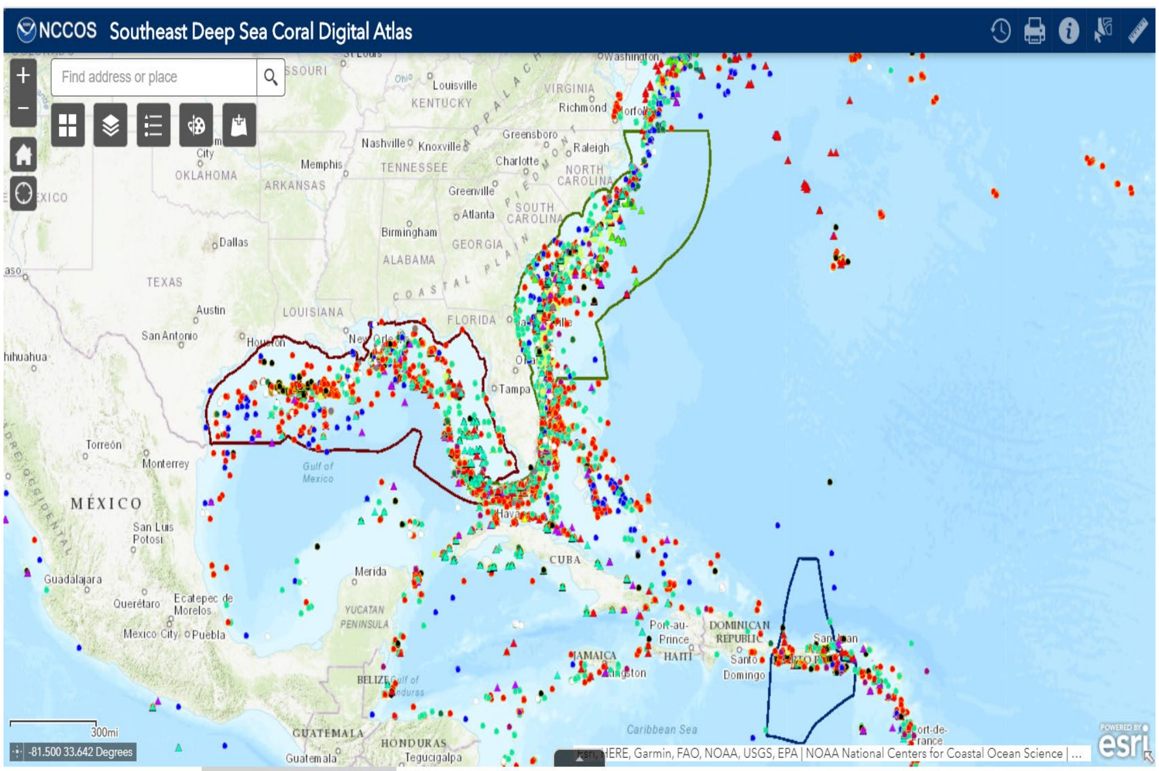


Figure 35. Screenshot of Southeast Deep Sea Coral Digital Atlas with SEDCI regions layer and DSCRTP Deep Sea Coral and Sponge Map Portal layer visible.

4.2 Photo ID Guides

Three new photo identification guides for deep-sea corals and sponges mark a 'best first effort' to combine *in situ* imagery with light and SEM microscopy in order to update species descriptions for deep-sea corals in the Gulf of Mexico and Southeast U.S. In addition to the guides, SEDCI also participated in an international taxonomic identification standardization project. The DSCRTP will continue to collaborate with this ongoing species identification effort.

4.2.1 Alcyonacean Octocorals of the Pinnacle Trend: A Photo-Identification Guide

Background and Objectives:

This photo identification guide was developed to document alcyonacean specimens (octocorals) collected and/or photographed from the Mississippi/Alabama Pinnacle Trend in the Northern Gulf of Mexico, as part of the Natural Resource Damage Assessment for the Deepwater Horizon oil spill (Figure 36). The project relied heavily upon *in situ* and *ex situ* photography, primarily from 2014 (Randall et al., 2014). The *in-situ* information was supplemented by light microscopy (LM) and scanning electron microscopy (SEM) to identify specimens to the lowest practical taxonomic level.

The guide provides detailed illustrations of the most common taxa observed at depths of 50 to 100m, but the collection of samples from DWH NRDA does not represent a census of every taxon that could occur in the area. The primary aim of this guide is to help support video/image-based analysis in future surveys of the Pinnacle Trend area and adjacent parts of the Northern Gulf of Mexico. The guide provides detailed remarks regarding the morphological characteristics and the recommended level of precision in terms of identifications from in-situ imagery. Such knowledge provides a baseline for future studies investigating these critical organisms.

Approach:

To generate this guide, imagery (*in situ, ex situ*, LM and SEM) from morphological and genetic analyses were compiled and compared to dichotomous keys and illustrations from the best available literature. New imagery was generated for taxa with incomplete documentation. Only those taxa with a high degree of certainty in the morphological identification were included in the guide. During this study there were several specimens (genera *Placogorgia, Nicella, Ellisella*, and *Villogorgia*) that contained unique but uncertain morphology and required further investigation. Also not included were taxa from the orders Pennatulacea, Antipatharia, Scleractinia, or the family Stylasteridae. A comprehensive resource for the Pinnacle Trend or the Gulf of Mexico should address these taxa as well as those presented here, and do so both morphologically and genetically.

Significant Results to Date:

This study compiled full color imagery (in situ, ex situ), with light and electron micrographs for 23 species for gorgonian octocorals from the 50-150 m depth range in the northern Gulf of Mexico (Figure 37). The effort produced new, original SEM plates for nine species illustrated for the first time. Of these, at least 13 species were reported as injured resources in literature associated with the damage assessment for Deepwater Horizon oil spill (Silva et al., 2016; Etnoyer et al., 2016). A dichotomous key is provided, in keeping with a Southeast U.S. guide to octocorals by DeVictor and Morton (2010). The information compiled in this guide should enhance the ability for video analysts and benthic ecologists to recognize these taxa in future surveys from survey images and from tissue samples to be analyzed in the laboratory.

Points of Contact:

Andrew Shuler (andrew.shuler@noaa.gov), CSS, Inc., in support of NOAA NCCOS MSE
Peter Etnoyer (peter.etnoyer@noaa.gov), NOAA NCCOS MSE

References and document links:

Deichmann, E. (1936) The Alcyonaria of the western part of the Atlantic Ocean. Memoirs of the M. C. Z. Harvard 53:1-317, pls. 1-37

Devictor ST and Morton SL. (2010) Identification guide to the shallow water (0–200 m) octocorals of the South Atlantic Bight. Zootaxa 2599: 1-62

Etnoyer PJ, Wickes LN, Silva M, Dubick JD, Balthis L, Salgado E, and MacDonald IR. (2016) Decline in condition of gorgonian octocorals on mesophotic reefs in the northern Gulf of Mexico: before and after the Deepwater Horizon oil spill. Coral Reefs 35:77-90

Randall M, Etnoyer P, Sulak K, MacDonald I. (2014) 2014 Mesophotic Cruise Report. NOAA NRDA Mesophotic Reefs Technical Working Group. deepseacoraldata.noaa.gov/library/2014_mesophotic_cruise_report/

Silva M, Etnoyer, PJ, and MacDonald, IR. (2016) Coral injuries observed at mesophotic Reefs after the Deepwater Horizon oil discharge, Deep-Sea Research Part II 129: 96-107

Publications from project:

Shuler AJ and PJ Etnoyer. (2020) Alcyonacean octocorals of the Pinnacle Trend: A photo-identification guide. NOAA Technical Memorandum NOS NCCOS 282. 56 pp. doi:10.25923/xzd1-z382

Images, maps, graphs, other key figures:

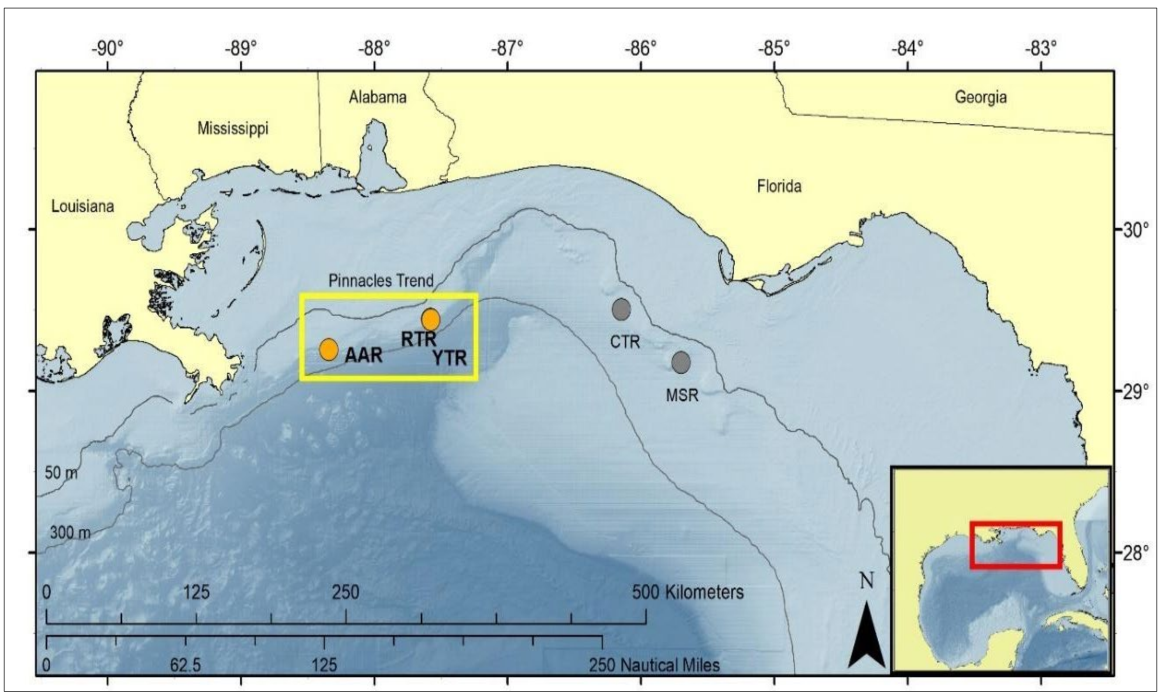


Figure 36. Map of the primary reefs surveyed during DWH NRDA - Roughtongue Reef (RTR), Yellowtail Reef (YTR), Alabama Alps Reef (AAR). Pinnacle Trend reefs are highlighted in the yellow box west of De Soto Canyon. Two additional reefs sampled east of De Soto Canyon are marked in grey, unique taxa from these locations were not included in this guide.

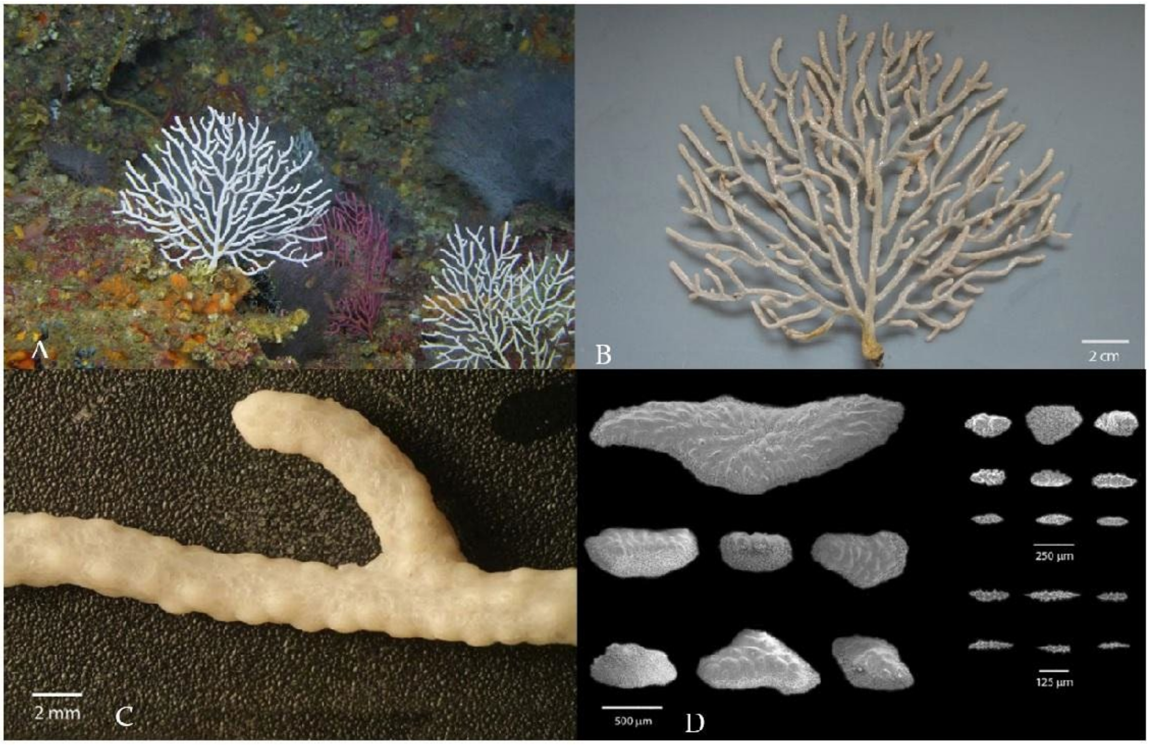


Figure 37. Representative panel of the four types of images included in this guide. A) In-situ image of *Thesea parviflora,* B) ex-situ image, C) light micrograph of axis, and D) sclerites imaged with a scanning electron microscope.

4.2.2 Photographic Catalog of Deep-Sea Corals Collected from the U.S. West Atlantic Margin by NOAA Ship *Okeanos Explorer* in Years 2017-2019

Background and Objectives:

SEDCI co-sponsored several cruises in partnership with OER aboard NOAA Ship *Okeanos Explorer*, using ROV *Deep Discoverer* to explore deep-sea habitats. Exploration revealed impressive diversity and abundance of deep-sea corals in many locations in the Gulf of Mexico, U.S. Caribbean, and waters of the Southeast U.S. Some of these corals were previously unseen in these areas.

A photo-identification guide for these corals was produced to provide a visual reference for commonly observed deep-sea corals in the SEDCI study area, as a shared resource for taxonomic identification of these organisms. With this release, NCCOS scientists have worked with taxonomists around the world to correlate *in situ* imagery of living corals to the preserved specimens archived at the Smithsonian National Museum of Natural History. The consistent identification and systematics of many of the taxa featured in this edition are essential for the valuation and protection of vulnerable marine ecosystems. We hope to continue to update this collection as new observations, additional expertise, and data become available.

Approach:

A list of samples, still images and corresponding metadata was obtained through the OER Digital Atlas for six cruises through the greater Southeast U.S. — EX1711, EX1803, EX1806, EX1811, EX1903, and EX1907 — spanning three years of fieldwork. The locations of samples for each region are shown in Figure 38.

A relational database was produced from data extracted from the OER data portal, and referenced to the DSCRTP National Database of Deep-Sea Corals and Sponges via their Catalog Number, when applicable. Many of the 117 specimens were analyzed by taxonomic experts. The corresponding identifications are indicated as confirmed by morphological analysis or confirmed by genetic analysis. Taxonomic identification status is indicated in the ID Verification Status field. Samples, that have not yet been taxonomically analyzed, or have been identified from photos only, are indicated as unconfirmed. Figure 39 illustrates a taxonomic entry or "plate" from the current publication. Entries in the catalog that are unconfirmed may indicate potential targets for future collections and research.

Significant Results to Date:

In total, 117 samples are illustrated in this publication. Of those, 62 were collected in the Southeast U.S. Atlantic, 31 in the Gulf of Mexico, and 24 in the U.S. Caribbean region. The gorgonians (Order Alcyonacea) are represented by 56 specimens in 10 families. The black corals (Order Antipatharia) are represented by 12 specimens in five families. The branching stony corals (Order Scleractinia) had five specimens in four families, while the lace corals (Order Anthoathecata, family Stylasteridae) included four collected specimens. Of all 117 samples curated for this volume, 25 were identified to species level, 72 to genus level, and 17 only to family level. The current catalog represents 47 distinct genera of deep-sea corals in 21 families.

From the total number of samples identified at any level, 24 are potential range. Seventy entries have been catalogued in NOAA's National Database of Deep-Sea Corals and Sponges (Cairns and Hourigan 2017). Several octocoral taxa in the families Plexauridae, and Isididae were not previously reported or collected in U. S. waters, based upon the most recent census (Hourigan, Etnoyer, and Cairns 2017).

Points of Contact:

Enrique Salgado (enrique.salgado@noaa.gov) CSS, Inc., in support of NOAA NCCOS MSE
Peter Etnoyer (peter.etnoyer@noaa.gov) NOAA NCCOS MSE

Additional Collaborators:

Thomas Hourigan, Steve Cairns, Scott France, Katharine Egan

References and document links:

Cairns SD, Hourigan T. A Comprehensive List of Known Deep-Sea Corals Occurring in the EEZ of the United States and its Possessions. SI Repository 2017.

Hourigan TF, Etnoyer PJ, Cairns SD (2017). The state of deep-sea coral and sponge ecosystems of the United States. US Department of Commerce, NOAA Technical Memorandum NMFS-OHC-4. Silver Spring, MD. 467 p

Publications from project:

Salgado EJ and Etnoyer PJ (2020). Photographic catalog of deep-sea corals collected from the US West Atlantic margin by NOAA Ship *Okeanos Explorer* in years 2017- 2019. NOS NCCOS 273. 132 pp. doi.org/10.25923/nnny-st44

Images, maps, graphs, other key figures:

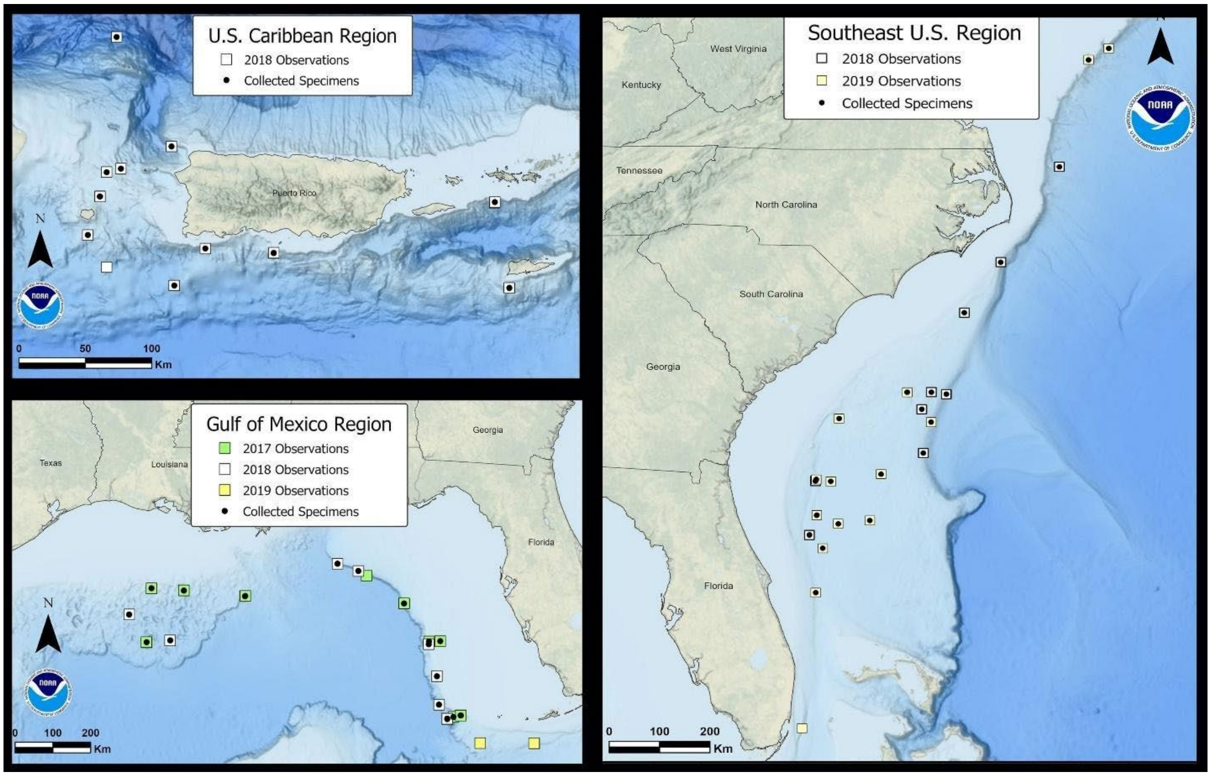


Figure 38. Coral samples collected in SEDCI study area by NOAA Ship *Okeanos Explorer*. Squares represent photographic observations, and black dots indicate where physical specimens were collected from 11/17 to 8/19.

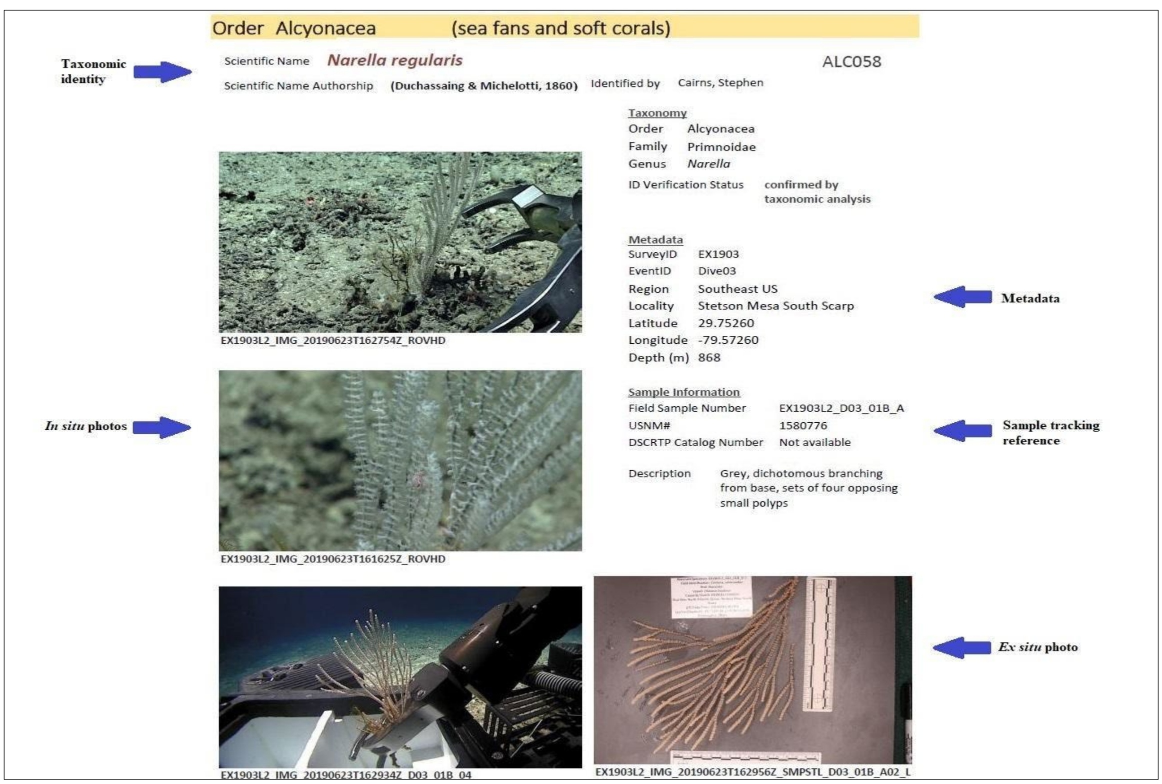


Figure 39. A screenshot from the photo-catalog representing a collected specimen of *Narella regularis*. Arrows indicate panels used to convey data types associated with each specimen.

4.2.3 Flower Garden Banks National Marine Sanctuary Species ID Field Guide

Background and Objectives:

Deep-sea coral and sponge ecosystems are scattered throughout the northern Gulf of Mexico, but are more concentrated amongst interconnected banks, reefs, and underwater features along the continental shelf. In an initiative to better characterize these largely under-studied communities throughout the northern Gulf of Mexico region, Flower Garden Banks National Marine Sanctuary has collected a variety of black corals (Antipatharia), octocorals (Octocorallia), stony corals (Scleractinia), soft corals (Alcyonacea), and sponges (Porifera) since the early 2000s. Through these collections, a species identification guide was created, to use as a tool to quickly and accurately identify deep-sea corals during ROV studies.

Approach:

Biological specimens were photographed *in situ* during dives using an ROV mounted camera, then sampled using the manipulator arm. The tissue samples were used to provide a laboratory based morphological identification and send samples for coral genomics to various partners (see Additional Collaborators below). For each specimen, the date, time, latitude, longitude, depth, and location name were recorded at the time of collection. Some opportunistic samples were also recovered from the ROV propellers, in which case, in situ photographs were not obtained, and precise location information was not available. Once specimens were collected, they were examined for commensal organisms, labeled, photographed, and inventoried in a database containing all relevant metadata. Any commensal organisms found on the specimens were removed and processed separately. Once photographed and labeled, specimens were preserved in an appropriate medium, such as ethyl alcohol and RNALater tissue storage reagent. Sample identifications were verified by partners (see Additional Collaborators below) through genetic analyses or morphometrics, or a combination of both.

Significant results to date:

Two-hundred seventeen biological specimens were collected during DSCRTP sponsored expeditions aboard R/V *Manta* between 2016–2018. Samples have been collected since the early 2000s from this region, so these provided some basis for identification. The existing FGBNMS species guides contain 43 specimens for Alcyonacea, 41 Antipatharia, 16 Porifera, and five Scleractinia, all of which were confirmed through morphometrics prior to the DSCRTP initiative. Of the 217 organisms collected with the DSCRTP, 50 identifications have been provided to FGBNMS staff to date. At least one was a confirmed new species of black coral: *Distichopathes hickersonae* (Figure 41; Opresko et al., 2020). These identifications are used to develop internal guides that assist in accurately identifying corals and sponges in videos and photographs produced during field operations; to develop robust species lists for the reefs and banks in the NWGoM to better inform management decisions; and to provide information about species distribution in this region. These identification guides are routinely updated and shared with the public online (octocorals, black corals, stony corals, and sponges).

Points of Contact:

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Marissa Nuttall – (marissa.nuttall@noaa.gov) CPC, in support of NOAA FGBNMS
Emma Hickerson – (emma.hickerson@noaa.gov), NOAA FGBNMS

Additional Collaborators:

Dennis Opresko (Smithsonian National Museum of Natural History), Mercer Brugler (University of South Carolina–Beaufort; formally with City University of New York), David Hicks (University of Texas Rio Grande Valley), Erin Easton (University of Texas Rio Grande Valley, Hicks graduate student), Andrew Shuler (National Centers for Coastal Ocean Science – Beaufort lab), Suzanne Fredericq (University of Louisiana at Lafayette)

References and Publications from project:

Opresko, DM, Goldman, SL, Johnson, R, Parra, K, Nuttall, M, Schmahl, GP, Brugler, MR. 2020. Morphological and molecular characterization of a new species of black coral from Elvers Bank, north-western Gulf of Mexico (Cnidaria: Anthozoa: Hexacorallia: Antipatharia: Aphanipathidae: Distichopathes). Journal of the Marine Biological Association of the United Kingdom, 100, 559-566. Article available online here.

Images, maps, graphs, other key figures:

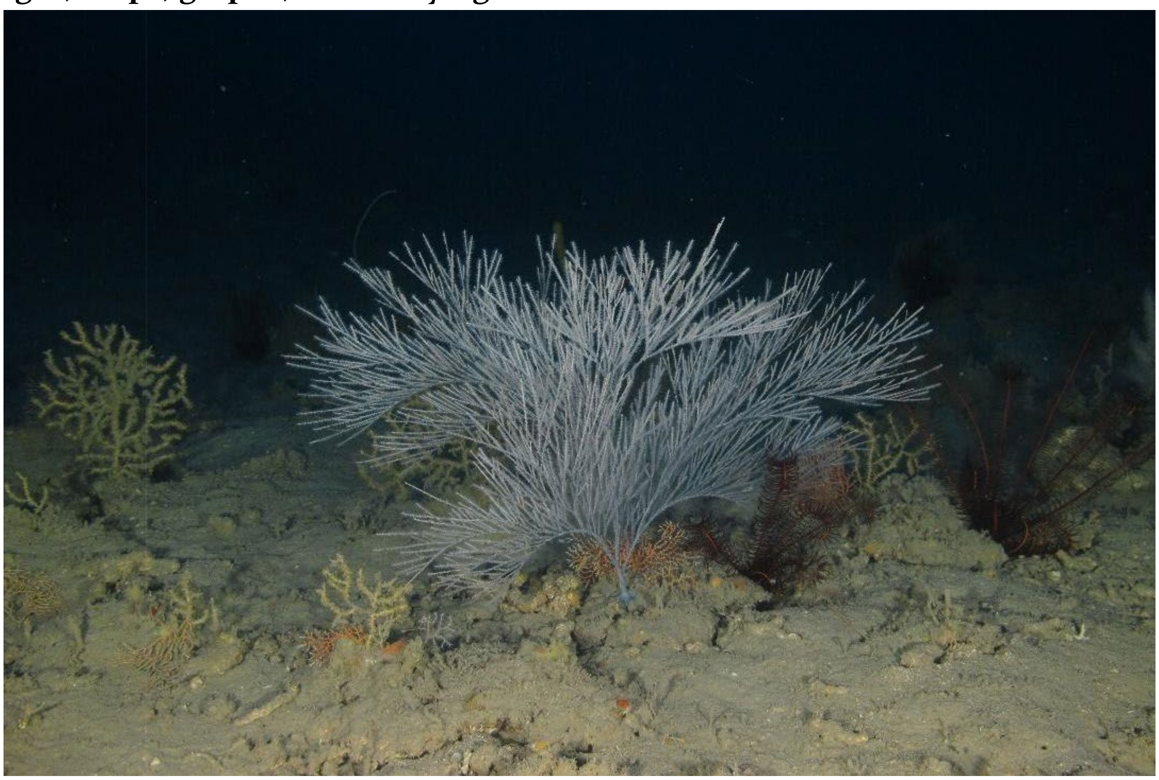

Figure 40. *Aphanipathes pedata* surrounded by *Scleracis* sp. and *Nicella* sp. in a deep reef habitat at Parker Bank observed in 2016 (DFH30) at 113 m depth. Photo: NOAA/UNCW–Undersea Vehicle Program.

Figure 41. New species of black coral, *Distichopathes hickersonae*, observed on an eroded outcrop at Elvers Bank in 2016 (DFH30) amongst large cup sponges at 172 m depth. Photo: NOAA/UNCW-Undersea Vehicle Program.

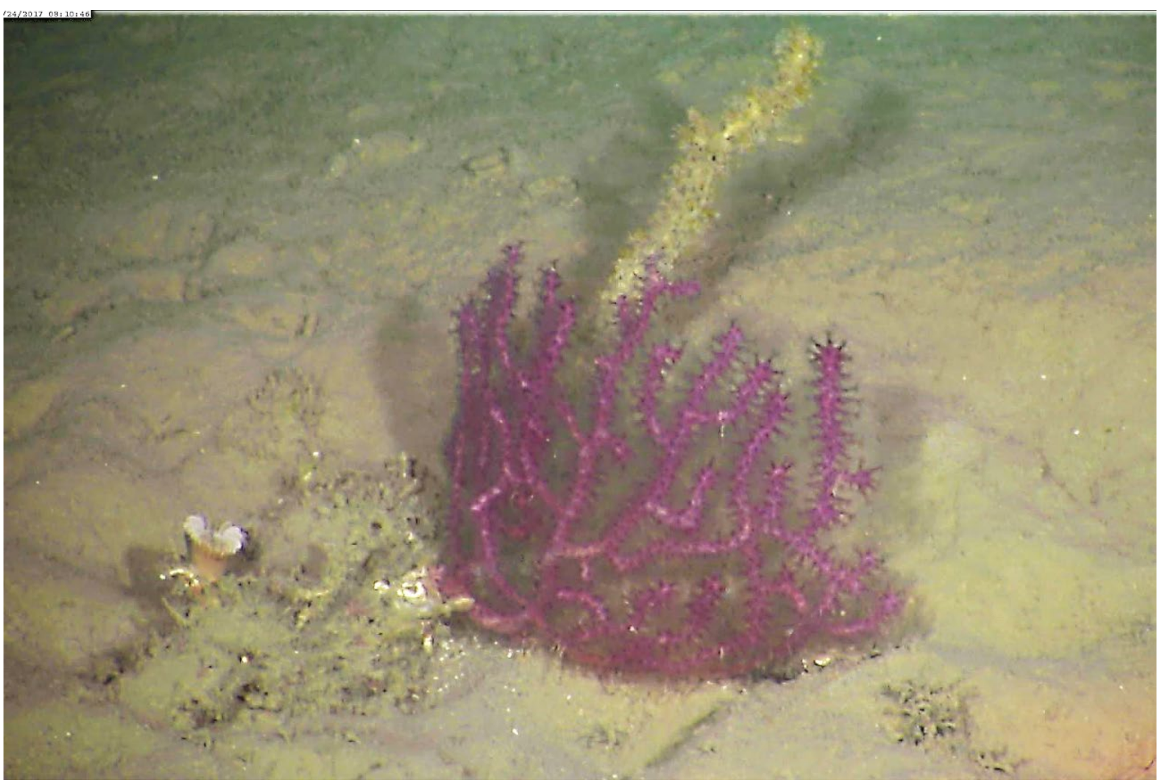

Figure 42. Plexauridae (possibly *Placogorgia rudis*) sampled from McGrail Bank in 2017 (DFH32). Observed in soft bottom habitat at 124m depth. Identification made through genetic analysis by Erin Easton. Photo: NOAA/UNCW-Undersea Vehicle Program.

Figure 43. *Swiftia exserta* collected from Rezak Bank in 2018 (DFH37) from a deep reef habitat at 86 m depth. Identification confirmed through genetic and morphological analyses by Erin Easton and Andrew Shuler. Photo: NOAA/UNCW-Undersea Vehicle Program.

4.2.4 SMarTaR-ID Collaboration

Background and Objectives:

The availability of high-quality video and images of deep-sea organisms is revolutionizing our understanding of these species and their ecosystems. These imaging technologies offer a less invasive, more cost-effective method to survey deep-sea corals and sponges than traditional methods such as trawls or grabs, and provide invaluable information on the surrounding environment. Lack of standardization among researchers in taxon identification and benthic survey protocols has led to problems with observer bias and the inability to combine datasets across studies. In addition, lack of a common reference standard limits efforts to apply machine-learning approaches to taxon identification.

The objective of this activity was to develop a consistent framework for identifying morphospecies, particularly of deep-sea corals and sponges from images.

Approach:

SEDCI participated in a new international collaborative effort, the Standardized Marine Taxon Reference Image Database (SMarTaR-ID) project, to develop a web-accessible standardized marine taxon reference image database. The project consists of a consortium of scientists from 29 organizations, including academia, industry and governments from eight nations bordering the North Atlantic.

Significant Results to Date:

SEDCI participated in an international workshop (December, 2017) and subsequent development of a proposed database structure to facilitate standardization of morphospecies image catalogs among research groups (Howell et al., 2019). In 2019, NOAA's National Database of Deep-Sea Corals and Sponges incorporated the SMarTaR-ID database framework (McGuinn et al., 2020). The deepwater coral image catalogs developed by SEDCI (Salgado & Etnoyer 2020; Schuler & Etnoyer 2020) build on this database structure, use high quality deep-sea images, and fill critical western Atlantic gaps in the trans-Atlantic effort. SEDCI researchers and the Deep Sea Coral Research and Technology Program will continue to participate with the international effort to improve reference guides for the identification of marine species from images.

Points of Contact:

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Additional Collaborators:

Kerry Howell & Jaime Davies - School of Biological and Marine Science, Plymouth University, UK, Daniel Wagner - Conservation International

References and document links:

Howell KL et al. 2019 A framework for the development of a global standardized marine taxon reference image database (SMarTaR-ID) to support image-based analyses. PLoS ONE 14(12): e0218904. doi.org/10.1371/journal.pone.0218904

McGuinn, RP, TF Hourigan, SL Cross, LM Dornback, PJ Etnoyer, DE Sallis, and HM Coleman. 2020. NOAA's National Database for Deep-Sea Corals and Sponges: 2020 Status Update. NOAA Tech. Memo. NMFS-OHC-007. 62 p.

4.3 Environmental Monitoring Project

This project had four components, which were designed as an experiment for monitoring oceanic environmental changes: 1) instrument calibration to measure oxygen, temperature and salinity, 2) water samples to determine ocean acidification, 3) long-term temperature loggers to gather data on ocean warming, and 4) development of long-term environmental proxies using deep-sea corals.

4.3.1 Enhancing Observations with Conductivity, Temperature, Depth, and Dissolved Oxygen (CTDO) Data

Background and Objectives:

Environmental parameters such as temperature, salinity, and oxygen help to define the ecological niche for deep-sea corals and sponges (Roberts et al., 2009). These measures can be employed to predict the distribution of species, estimate the timing of reproductive events, and even predict harm to species if thresholds are exceeded for some duration. These parameters are important, but very difficult to acquire in the deep-sea, particularly within proximity to benthic animals.

Remotely operated vehicles (ROVs) are increasingly equipped with environmental sensors attached to the vehicle. Conductivity-temperature-depth (CTD) sensors on the ROVs can provide profiles of the water column on descent, then produce many values per second while on-bottom, over areas close to the seafloor, where deep-sea corals and sponges live and grow.

Approach:

The six research cruises conducted aboard NOAA Ship *Okeanos Explorer* (EX1711, EX1803, EX1806, EX1811, EX1903 and EX1907) contributed most substantially to this effort, in cruises to the Caribbean, the Southeast U.S. and Gulf of Mexico. The *Deep Discoverer* ROV used a Sea Bird 9/11+ CTD with light scattering (LSS), dissolved oxygen (DO), and oxygen reduction potential (ORP) sensors to collect data from these cruises. The cruises had depth ranges from 250-5000 m, and temperature and dissolved oxygen ranges from 2.1-19.0 °C and 2.5-8.3 mg/L respectively. The SEDCI 2017 expedition aboard NOAA Ship *Nancy Foster* worked along the West Florida Shelf to collect water column profiles for these parameters and for aragonite saturation.

To visualize the wide range of environmental parameters, a dive-level table was created for each NOAA Ship *Okeanos Explorer* cruise using the Coastal and Marine Ecological Classification Standard (CMECS) terminology to help understand the environmental niches explored in these three regions. The tables contain Geoform, Water Column and Biotic data and can be customized for specific projects. A subsample of one of the tables is shown in Table 4.

Significant Results to Date:

These data provide an important window into the environmental niche for *Lophelia* reefs and other species in the Southeast U.S. and around the world. On the West Florida Shelf, *Lophelia* reefs were between 400-600 m depth, and typically within 2.8-3.2 ml/l of dissolved oxygen, and 7.5-10 °C. Salinity was stable, as expected, between 34.7 and 35.0 PSU in observed *Lophelia* reef habitats (Wagner et al., 2018). CTD profile plots show gradual temperature declines from surface waters at ~30 °C, until they begin to stabilize between 6-8 °C at 500 m depth. Oxygen levels decrease dramatically near 100 m, then stabilize around 3 ml/L beyond 200 m. This water column pattern appears to be consistent across the West Florida Shelf region (Figure 44).

Through this effort, 16,779 new records from NOAA Ship *Okeanos Explorer* are now annotated with depth, geo-position, temperature, salinity, and oxygen values. Many of these are joined to seafloor imagery, with species counts. All records are archived and served through DSCRTP. The data are useful for ecological niche modeling, circulation modeling, model cross-validation, and quality control.

Point of Contact:

Peter Etnoyer (peter.etnoyer@noaa.gov), NOAA NCCOS MSE

References and document links:

Roberts, J. M., Wheeler, A., Freiwald, A., & Cairns, S. (2009). Cold-water corals: the biology and geology of deep-sea coral habitats. Cambridge University Press.

Wagner D, Kilgour M & Etnoyer PJ (2018). Expedition Report: 2017 Southeast Deep Coral Initiative (SEDCI) expedition aboard NOAA Ship *Nancy Foster* (NF-17-08: August 12-31, 2017). NOAATechnicalMemorandum NOS NCCOS 244. Silver Spring, MD. doi:10.7289/V5/TM-NOS-NCCOS-244.

Images, maps, graphs, other key figures:

Table 4. A condensed version of the dive-level summary table created for each that shows Coastal and Marine Ecological Classification Standard (CMECS)-compliant environmental parameters. This table is for EX1907 off the Southeast coast of the U.S.

Dive #	Bottom Time	Locality	CMECS Geoform	CMECS Biotic Habitat	CMECS Depth Zone	Depth (m) Min	Depth (m) Max	Temp (°C) Min	Temp (°C) Max	Salinity (PSU) Min	Salinity (PSU) Max	Oxygen (mg/L) Min	Oxygen (mg/L) Max
1	6:50	Southern Blake Plateau	Ridge, Slope, Mounds	Deepwater/Coldwater Stony Coral Reef	Mesobenthic	822	870	5.646	7.040	35.010	35.071	3.862	5.396
2	9:05	Million Mounds East	Mounds, Slope, Authigenic Carbonate Outcrop Slabs	Deepwater/Coldwater Stony Coral Reef	Mesobenthic	748	825	8.215	8.522	35.034	35.082	2.959	4.694
3	3:51	Stetson Mesa West	Ridge, Shelf Basins, Slope, Mounds	Deepwater/Coldwater Stony Coral Reef	Mesobenthic	763	808	8.002	8.582	35.107	35.123	3.289	3.715
4	6:56	Stetson Mound Field 1	Mounds, Slope, Authigenic Carbonate Outcrop Slabs	Colonized Deepwater/Coldwater Reef	Mesobenthic	817	835	8.082	8.544	35.065	35.141	3.424	3.638
5	2:36	Stetson Mound Field 2	Mounds, Slope	Faunal Bed	Mesobenthic	811	829	8.560	8.574	35.095	35.097	3.154	3.310
6	8:57	Central Blake Plateau	Mounds, Plateau, Slope	Sponge Colonized Deepwater/Coldwater Stony Coral Reef	Mesobenthic	766	842	8.112	10.15	35.111	35.293	3.154	3.851
7	6:41	Nodule Field	Plain	Sparse biota - no CMECS terminology	Mesobenthic	801	807	8.906	8.939	35.157	35.164	3.165	3.366
8	8:35	Miami Terrace	Marine Terrace, Authigenic Carbonate Outcrop Slabs, Boulder Field	Colonized Deepwater/Coldwater Reef	Mesobenthic	508	563	6.928	7.621	34.883	34.943	2.941	3.215
9	6:26	Key Largo Deep	Plain	Faunal Bed/Soft Sediment Fauna	Mesobenthic	590	641	6.252	6.610	34.865	34.907	3.165	3.577
10	8:08	Pourtalès Terrace	Marine Terrace, Mound, Ridge, Scarp, Authigenic Carbonate Outcrop Slabs, Plateaus	Diverse Colonizers, Faunal Bed	Mesobenthic	347	404	9.104	10.05	34.547	35.188	2.471	2.744
11	6:08	Key West Deep	Scarp, Wall, Mounds, Plain, Marine Terrace	Diverse Colonizers	Bathybenthic	1132	1218	4.297	4.321	34.949	34.953	4.675	4.910
12	6:51	Berg Bits - SW of Dry Tortugas	Plateau, Mound, Scarp/Wall, Rock Outcrop	Diverse Colonizers	Mesobenthic	928	973	4.765	4.831	34.923	34.928	4.283	4.454

Temperature: Very Cold to Cool Salinity: Euhaline Oxygen: Hypoxic to Oxic.

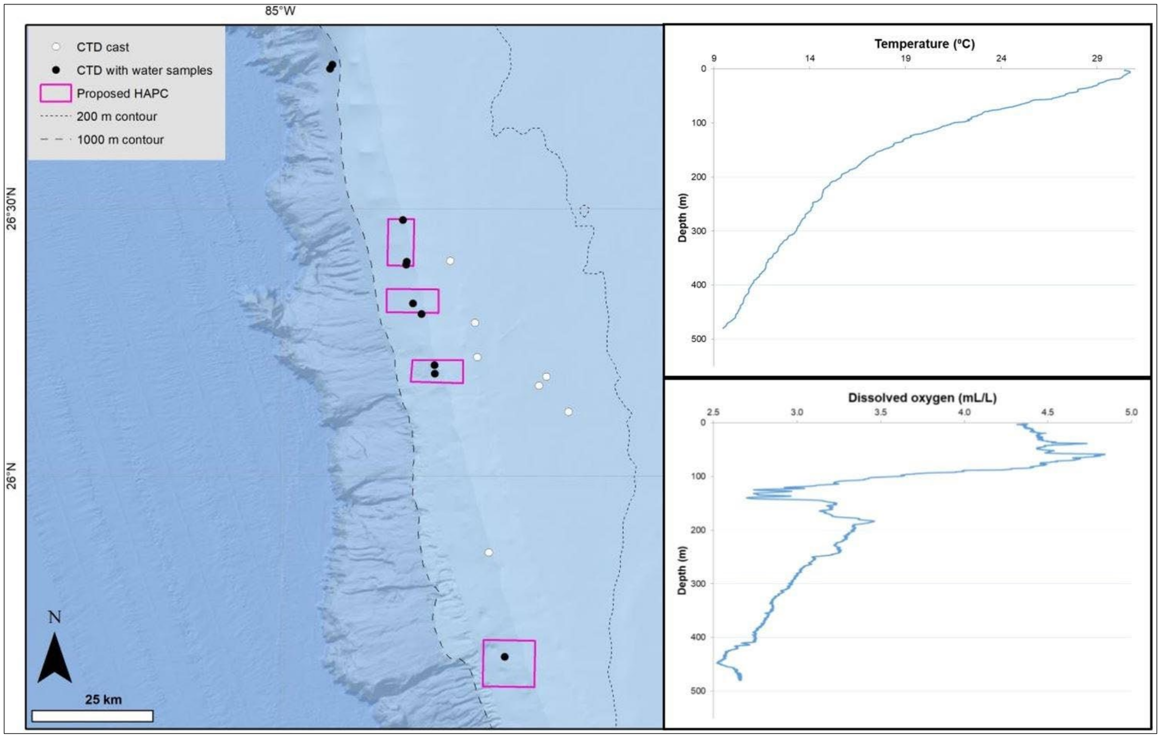

Figure 44. Map of CTD cast locations in the West Florida shelf study area. The temperature and oxygen profiles were taken from the ROV-mounted sensor during NF 1708 Dive 7, and represent typical profiles for the study area.

4.3.2 Carbonate Chemistry Report for Water Samples from SEDCI Expedition aboard NOAA Ship *Nancy Foster* (NF1708) in 2017

Background and Objectives:

In 2017 NOAA launched the expedition 'Southeast Deep Coral Initiative: Exploring Deep-Sea Corals Ecosystems of the Southeast U.S.'. The survey explored deep-sea coral habitat along West Florida Shelf, using ROV *Odysseus* aboard NOAA Ship *Nancy Foster*. The survey made 13 ROV dives over coral mounds, rocky ridge, and flat seafloor, comparing coral abundance and diversity in each of these environments. The reef-forming scleractinian coral *Lophelia pertusa* (=*Desmophyllum pertusum*) was present in several areas (Wagner et al., 2018).

Deepwater stony corals are sensitive to carbonate chemistry (Georgian et al., 2016). The skeletons of scleractinian corals are aragonitic, made of a form of calcium carbonate. The health and condition of the colonies are correlated with aragonite saturation, or omega (Ω), a measure of the tendency for aragonite to dissolve in seawater. Values of aragonite saturation lower than Ω = 1 are considered detrimental to coral growth and condition, whereas values higher than 1 are generally conducive to coral growth.

In the northern Gulf of Mexico, *L. pertusa* reefs are typically found in the depth range from 300 to 600 m, at temperatures of 8–12°C and relatively low aragonite saturation states of 1.2–1.5 and pH of 7.85 to 8.00 (Lunden et al., 2013). In contrast, Ω on a shallow South Pacific coral reef ranges from 2.40 to 3.70, and the pH can range from 7.20 to 8.20 (Mollica et al., 2019).

In order to understand the carbonate chemistry along West Florida slope, and how it varied with depth, a CTD-rosette was deployed from Nancy Foster 17 times in the vicinity of deep coral reefs over the course of 13 days, mostly to 400-500 m depth, but as deep as 1,000 m. Aragonite saturation state values were calculated from bottle samples ranging from 20 m to 1000 m water depth. In total, 59 water samples were processed for carbonate chemistry analyses. The results of these analyses are presented here.

Approach:

In total, 58 bottle samples were analyzed for total CO_2 (TCO_2) and total alkalinity (TA) by Kim Yates at the USGS laboratory facility in Gainesville, Florida. One bottle arrived at the testing facility broken and could not be analyzed. The lab used a closed cell acidification module and procedure to convert all dissolved TCO_2 in the sample to CO_2 gas, which was then analyzed in a UIC coulometer. This measurement is independent of temperature.

The aragonite saturation state ($\Omega_{aragonite}$) for all bottle samples was calculated using the program "CO2calc" (v.1.0) with data provided by USGS data analysis and NOAA cruise report for the expedition (Wagner et al., 2018). Input parameters for aragonite saturation calculations included the following data collected from the CTD: *in situ* temperature (°C), salinity (PSU), and pressure (decibars). Pressure was converted from depth in meters using an algorithm provided by Seabird Electronics (see SBE App. Note 69 for reference). Additional input parameters for aragonite saturation calculation included total alkalinity (TA, $\mu mol \cdot kg^{-1}$) and total carbon dioxide (TCO_2, $\mu mol \cdot kg^{-1}$) measured from preserved bottle samples at the St. Petersburg Coastal and Marine Science Center. The following constants were used in all $\Omega_{aragonite}$ calculations: K1, K2 from Mehrbach et al. (1973) as refit by Dickson and Millero (1987); $KHSO_4$ from Dickson (1990), and air-sea flux from Wanninkhof (1992).

Significant Results to Date:

Aragonite saturation state values ranged from a high of 4.16 at 20 m water depth at the Many Mounds site to a low of 1.12 at 800 m water depth at the North Wall site. Generally, $\Omega_{aragonite}$ decreased rapidly with depth, as expected. The high rate of change coincided with occurrence of the thermocline (20-200 m) at each site, and approaches a soft asymptote of ~1.3-1.4 at approximately 400 m (Figure 45).

The scleractinian cold-water coral *Lophelia pertusa* was collected from the North Reed (500 m), Many Mounds (430-480 m), and *Okeanos* Ridge (521 m) sites, where the $\Omega_{aragonite}$ is roughly 1.2-1.3. Differences in $\Omega_{aragonite}$ from bottles collected during the day versus night were minimal, but highest in samples near the surface, where there was difference of 0.1-0.2 in $\Omega_{aragonite}$ at 20 m depth. You can find information about these archived data at accession.nodc.noaa.gov/0209115 under the title 'Aragonite Saturation State in Deep-Sea Coral Habitats collected from *Nancy Foster* in Gulf of Mexico from 2017-08-14 to 2017-08-30.'

Conclusion:

Generally, the values of $\Omega_{aragonite}$ in *Lophelia pertusa* habitats sampled during the expedition were 1.2–1.3 between 430-520 m depth. These values are similar to those reported from other published studies in the region and broader area. At similar depths throughout the Gulf of Mexico, areas with *Lophelia pertusa* have $\Omega_{aragonite}$ ranging from 1.24-1.69 (Georgian et al., 2016, Lunden et al., 2013). At canyon sites along the U.S. Atlantic margin, *Lophelia* was observed in areas with $\Omega_{aragonite}$ ranging from 1.41-1.44 (Brooke and Ross, 2014). These results suggest that *Lophelia* along the east coast of Florida experiences similar carbonate chemistry regimes as *Lophelia* along the U.S. Atlantic margin. However, the values reported here are relatively low, compared to the range observed in other regions of the Southeast U.S.

The study could be improved by replicating bottle sample collections at depth, and by increased sampling periodicity over daily/seasonal scales. With an enhanced sample size and replicated design, testing for statistical significance between day and night samples would be possible, which would aid in identifying contributions from photosynthesis and respiration at the surface to the carbon dynamics of cold-water coral habitats at depth.

Point of Contact:

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References and document links:

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Mehrbach C, Culberson CH, Hawley JE, & Pytkowicx RM (1973). Measurement of the apparent dissociation constants of carbonic acid in seawater at atmospheric pressure. Limnol. Oceanogr. 18:897-907.

Mollica, NR, W Guo, AL Cohen, K-F Huang, GL Foster, HK Donald, AR Solow. (2019) OA affects coral growth by reducing density. Proc Nat Acad Sci. 115 (8) 1754-1759.

Wagner D, Kilgour M, & Etnoyer PJ (2018). Expedition Report: 2017 Southeast Deep Coral Initiative (SEDCI) expedition aboard NOAA Ship *Nancy Foster* (NF-17-08: August 12-31, 2017). NOAA Technical Memorandum NOS NCCOS 244. Silver Spring, MD.

Wanninkhof R (1992). Relationship between wind speed and gas exchange over the ocean. J. Geophys. Res. 97:7373-7382.

Images, maps, graphs, other key figures:

Table 5. Water samples by depth bin from NF17-08 at West Florida Slope sites.

Depth bin (m)	# of samples	Mean Total Alkalinity (µmol·kg-1) ± S.D.	Mean TCO2 (µmol·kg-1) ± S.D.	Mean $\Omega_{aragonite}$ ± S.D.
0-49	9	2379.7 ± 13.7	2030.6 ± 16.6	3.99 ± 0.08
50-99	0	n/a	n/a	n/a
100-149	9	2392.5 ± 8.1	2159.7 ± 12.4	2.57 ± 0.22
150-199	1	2352.7	2180.4	1.94
200-249	7	2353.0 ± 11.9	2175.2 ± 7.6	1.96 ± 0.18
250-299	4	2344.8 ± 22.3	2184.5 ± 14.5	1.79 ± 0.35
300-349	5	2333.4 ± 12.1	2190.6 ± 8.6	1.61 ± 0.18
350-399	6	2325.7 ± 8.2	2195.9 ± 7.3	1.48 ± 0.13
400-499	8	2317.2 ± 11.0	2202.0 ± 4.3	1.33 ± 0.11
500-699	5	2311.7 ± 1.5	2211.5 ± 2.8	1.17 ± 0.03
700-1000	4	2319.2 ± 2.6	2209.5 ± 3.5	1.14 ± 0.01

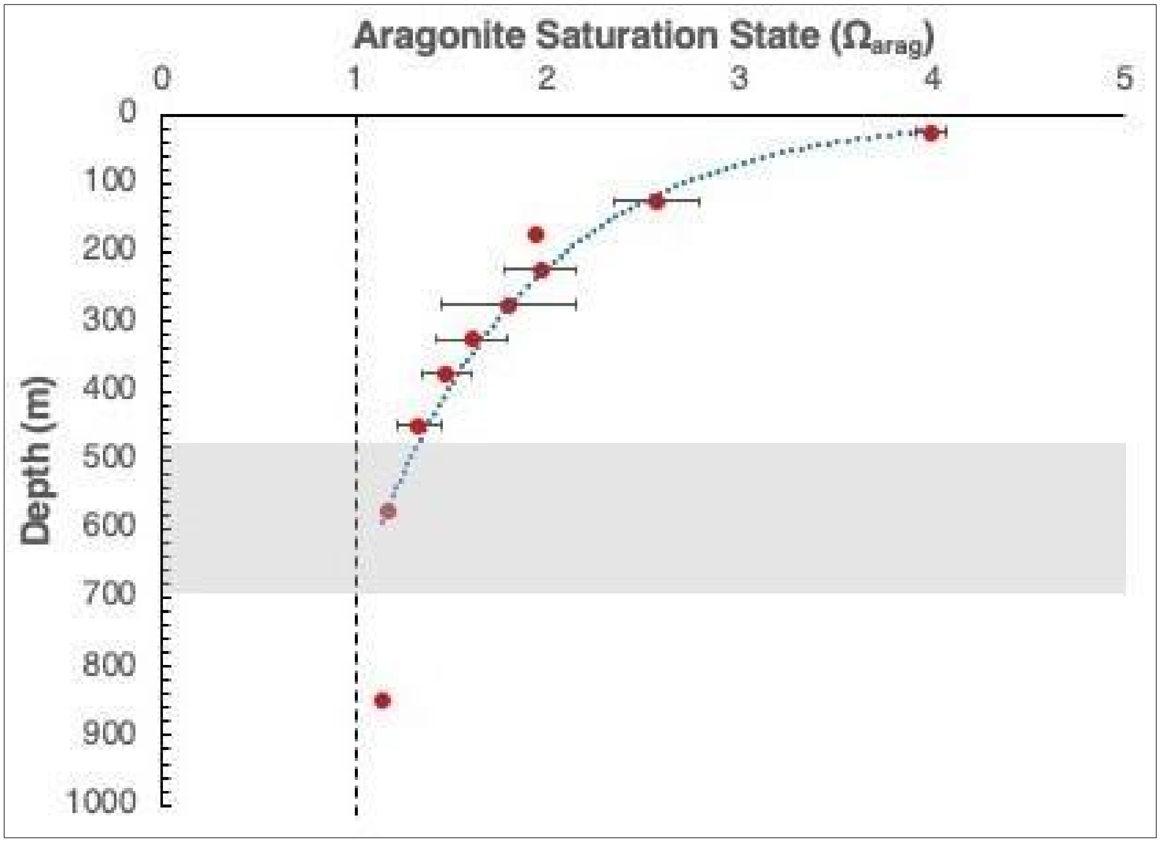

Figure 45. Water column profile showing average omega aragonite with depth. Data points are average omega aragonite ($\Omega_{aragonite}$) within each depth bin, error bars are standard deviation of the mean. The black dotted line represents $\Omega_{aragonite}$ = 1.0, and the shaded gray box represents the depth range of *Lophelia* pertusa in this region (438-693 m).

4.3.3 Temperature Logger Deployment

Background and Objectives:

Marine heatwaves are an emerging concern for deep-sea corals. Studies have shown that marine heatwaves are increasing in frequency and duration (Oliver et al., 2018), and they can occur in deep water (Scannell et al., 2020). Water temperature is one of the primary environmental factors controlling coral health and growth on shallow water reefs. Temperature anomalies are highly correlated with incidence of coral bleaching and disease in zooxanthellate corals. The cooler temperatures of the mesophotic zone are thought to provide refugia from surface anomalies, but it has recently been shown that anomalies occur in the Channel Islands NMS as deep as 100 m and they are not always correlated with surface events (Gugliotti et al., 2019). Corals at depths of 50-100 m are also vulnerable to extreme temperatures. However, the frequency and extent of these deepwater anomalies can only be inferred by surface measures (Gugliotti et al., 2019).

Approach:

This small project deployed a series of temperature loggers from depths of 40 to 230 m, at two locations, adjacent to shallow water coral reefs. The first deployment was aboard NOAA Ship *Nancy Foster* in the Caribbean Sea in the southwest Puerto Rico region on expedition NF1804 on July 5th, 2018. HOBO TidbiT v2 temperature loggers (model UBTI-0001) were placed at depths 40, 76, 120, 229 m by ROV *Mohawk*, and programmed to collect data hourly, which should allow them to record data until year 2021. The second deployment was in the Gulf of Mexico in the

Flower Garden Banks region aboard R/V *Manta* on expedition DFH35 on July 26, 2018. HOBO TidbiT v2 temperature loggers (model UBTI-0001) were placed at depths 48, 97, and 98 m by ROV *Mohawk*, programmed for hourly data collection, they should also record until 2021.

Significant Results to Date:

The temperature loggers could not be recovered due to COVID related ship cancellations in 2020, but the locations are available in Table 6. The data loggers are targeted for recovery in 2022.

Point of Contact:

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References and document links:

Gugliotti, E. F., DeLorenzo, M. E., & Etnoyer, P. J. (2019). Depth-dependent temperature variability in the Southern California bight with implications for the cold-water gorgonian octocoral *Adelogorgia phyllosclera*. Journal of Exp. Marine Biology and Ecol., 514, 118-126.

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Scannell, H. A., Johnson, G. C., Thompson, L., Lyman, J. M., & Riser, S. C. (2020). Subsurface evolution and persistence of marine heatwaves in the Northeast Pacific. Geophysical Research Letters, 47(23), e2020GL090548.

Images, maps, graphs, other key figures:

Table 6. Location of temperature loggers deployed in the Gulf of Mexico and the Caribbean in 2018.

Date	Locality	Logger	Latitude	Longitude	Depth (m)
07/05/2018	Ponce, Puerto Rico	C	17.86695	-66.58552	229
07/05/2018	Ponce, Puerto Rico	B	17.86574	-66.57922	120
07/05/2018	Ponce, Puerto Rico	A	17.86537	-66.57849	76
07/05/2018	Ponce, Puerto Rico	E	17.86512	-66.57619	40
07/26/2018	East Flower Garden Bank	T	27.91702	-93.61760	48
07/26/2018	West of East Flower Garden Bank	U	27.91359	-93.63678	98
07/26/2018	Far west of East Flower Garden Bank	R	27.91038	-93.65817	97

4.3.4 Geospatial Analysis of Deep-Sea Environments Using ROV Video Data with the Coastal and Marine Ecological Classification Standard (CMECS)

Background and Objectives:

NOAA National Centers for Environmental Information (NCEI) maintains a vast repository of ROV imagery and video data. These data represent a significant oceanographic resource with immense value for the scientific community. However, for scientists not directly involved in the collection of those data, the amount of time and effort required to review it (tens to hundreds of hours) just to determine its potential value to their research can be overwhelming. Thus, the goal of this project is to develop open-source automated video data mapping tools, based upon the widely adopted CMECS (USGS, 2012), to enhance access and utilization of ROV video data by the broader oceanographic research community.

This project specifically supported Mississippi State University personnel to design an automated system for the digital mapping of seafloor substrate observed in video data acquired during expeditions aboard NOAA Ship *Okeanos Explorer*. The primary objective is to produce a series of open-source Python scripts, and standard operating procedures (SOPs) that automate the generation of color-coded seafloor substrate maps and resultant GIS polygon files. The polygon files show seafloor area viewed and substrate composition, based upon ROV and shipboard data records. The substrate classes are classified using CMECS, which has been broadly adopted by NOAA. The source data used are scientific annotations created in Ocean Networks Canada's (ONC) SeaTube v2 software, by scientists participating in NOAA Ship *Okeanos Explorer* expeditions, as well as navigation data and environmental sensor observations from the ROV *Deep Discoverer*. The resulting Python scripts and supporting SOP documents will allow users to visualize geospatial relationships within ROV video data in a new way and with a degree of automation that was not previously possible. This project builds on processes for automated extraction and digital mapping of ROV data initially developed through a collaboration between the NOAA OER, NCEI, and the Northern Gulf Institute at Mississippi State University (Ruby, 2017).

Approach:

To meet the primary project objective, three Python script modules and associated SOP will be generated. The first script module extracts ROV navigational data and substrate observations from the full annotation record for all dives from NOAA Ship *Okeanos Explorer* cruises EX1803, EX1806, and EX1903L2. The second script module generates a digital map of the ROV dive track (line feature) and estimated seafloor areas (polygon features) imaged by the primary ROV camera using a series of overlapping "viewshed" polygons. Viewsheds are determined based upon the view angle geometry of the ROV camera system at regular intervals (1 Hz). The third script module assigns classification values to the viewshed polygons based upon temporally coincident substrate annotations in the SeaTube v2 software generated by participating scientists (primarily from the Etnoyer Lab at Hollings Marine Laboratory in Charleston, South Carolina). These substrate annotations were based in four categories that refer to the primary (>50%) and secondary substrates: Hard/Hard, Hard/Soft, Soft/Hard and Soft/Soft (Bassett et al., 2017). A sub-routine in the third script module converts annotations into CMECS-compliant substrate units. CMECS classifications for overlapping sections of adjacent viewsheds are determined based on weighted probabilistic integration of the two constituent classifications. All scripts generated for this project will be designed to work with open source QGIS software and published on public code repositories in order to support the broadest possible adoption and application.

In addition to python scripts, new procedures (SOPs) will be developed for live annotation of NOAA Ship *Okeanos Explorer* ROV dives using SeaTube v2. SeaTube v2 (ONC) is used by NOAA

OER for meeting data accessibly objectives while also retaining live annotation and post-dive archival data. These procedures will be designed to incorporate a new annotation protocol that will yield georeferenced maps with more detail and better reproducibility.

Significant Results to Date:

Representative imagery of each CMECS substrate class from the project data set has been compiled by NOAA collaborators P. Etnoyer and R. Bassett. This representative imagery portrayed substrate classes of rock, coarse and fine sediment in varying proportions. Features and substrate types varied greatly across dives, from large boulders and rock walls to fine sediment. The project data set from the three previously mentioned NOAA Ship *Okeanos Explorer* expeditions encompassed 40 dives and more than 9,200 images. Additionally, they created an SOP for substrate annotations in SeaTube v2.

Jacob Freeman, a Masters student at Mississippi State University, completed an initial version of the Python script module one, which extracts ROV navigational data and substrate observations from the full ROV annotation record. Additionally, he has partially completed Python script module two. Currently, that script module generates dive track and viewshed shapefiles as well as resultant digital maps in QGIS. Jacob has also created draft SOP documents for these scripts. See Figures 46-48 for examples of digital maps generated with the created script modules.

Point of Contact:

Adam Skarke (adam.skarke@msstate.edu), Mississippi State University

Additional Collaborators:

Peter Etnoyer, NOAA NCCOS MSE; Mashkoor Malik, NOAA OER; Sharon Mesick & Scott Cross, NOAA NCEI; Thomas Hourigan, NOAA Fisheries, DSCRTP; Rachel Bassett, CSS, Inc. in support of NOAA NCCOS MSE

References and document links:

The project Python/QGIS code is uploaded to GitHub here: https://github.com/askarke/ROV_Video_Mapping_CMECS

Bassett, RD, M Finkbeiner, PJ Etnoyer. (2017), Application of the Coastal and Marine Ecological Classification Standard (CMECS) to Deep-Sea Benthic Surveys in the Northeast Pacific: Lessons from Field Tests in 2015. NOAA Tech Memo NOS NCCOS 228, NOAA National Ocean Service, Charleston, SC 29412. 49 pp. coastalscience.noaa.gov/publications/handler.aspx?key=9289

Etnoyer, PJ, M Malik, D Sowers, C Ruby, R Bassett, J Dijkstra, N Pawlenko, S Gottfried, K Mello, M Finkbeiner, and A Sallis. 2018. Working with video to improve deep-sea habitat characterization. In Raineault, N.A, J. Flanders, and A. Bowman, eds. 2018. New frontiers in ocean exploration: The E/V *Nautilus*, NOAA Ship *Okeanos Explorer*, and R/V *Falkor* 2017 field season. Oceanography 31(1), supplement, 126 pp. doi.org/10.5670/oceanog.2018.supplement.01

Ruby, C. (2017), Application of Coastal and Marine Ecological Classification Standard (CMECS) to remotely operated vehicle (ROV) video data for enhanced geospatial analysis of deep-sea environments. M.S. thesis, 266 pp., Mississippi State University.

U.S. Geological Survey (2012), Coastal and Marine Ecological Classification Standard, Fed. Regist., 77(170), 53224–53225.

Publications from project:

To date:

Etnoyer, P., R. Bassett, C. Ruby, A. Skarke, M. Malik (2019), Leveraging telepresence and GIS technology to create rapid substrate distribution maps from ROV video and support studies of deep-sea corals. Abstract ISDSC7_035 presented at the 7th International Symposium on Deep-Sea Corals, Cartagena, Columbia, 29 Jul.-2 Aug.

Anticipated:

Freeman, J. (2022) Geospatial analysis of deep-sea benthic environments through application of the Coastal and Marine Ecological Classification Standard to ROV video data. Masters Thesis: Mississippi State University, Mississippi State, MS, USA.

Freeman, J., A. Skarke, and C. Ruby (2022) Geospatial analysis of deep-sea benthic environments through application of the Coastal and Marine Ecological Classification Standard to ROV video data. Abstract accepted at 2022 Ocean Sciences Meeting, Honolulu, 27 Feb-04 Mar.

Images, maps, graphs, other key figures:

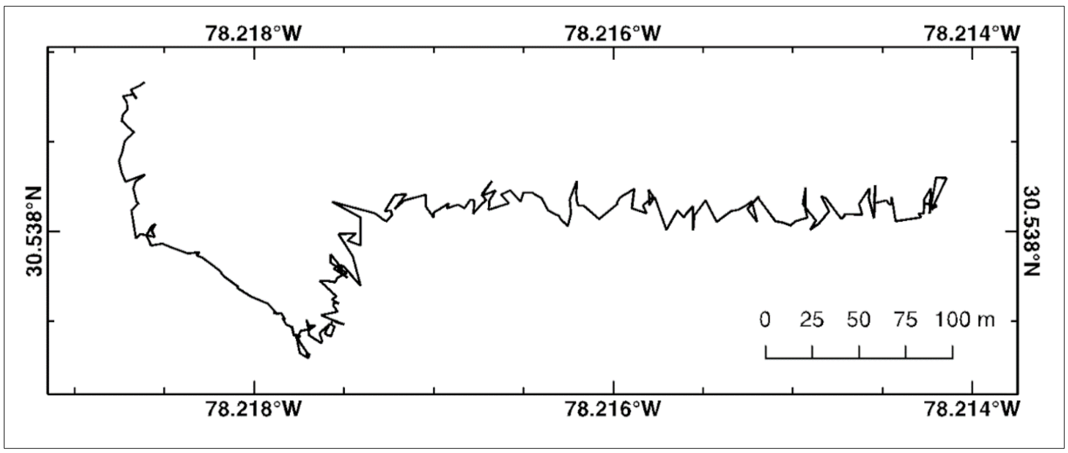

Figure 46. Shapefile (line) of ROV dive track for EX1903L2 Dive 05.

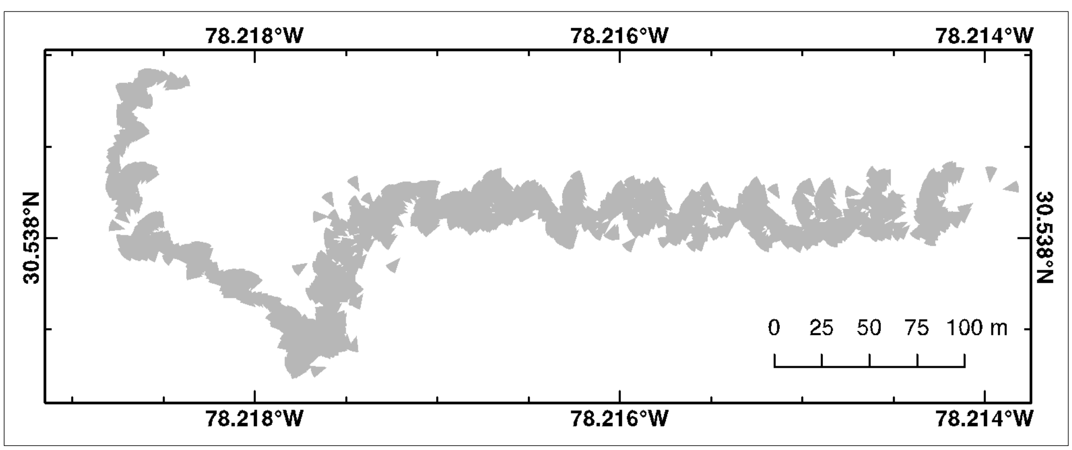

Figure 47. Shapefile (polygon) of seafloor area imaged by ROV camera for EX1903L2 Dive 05.

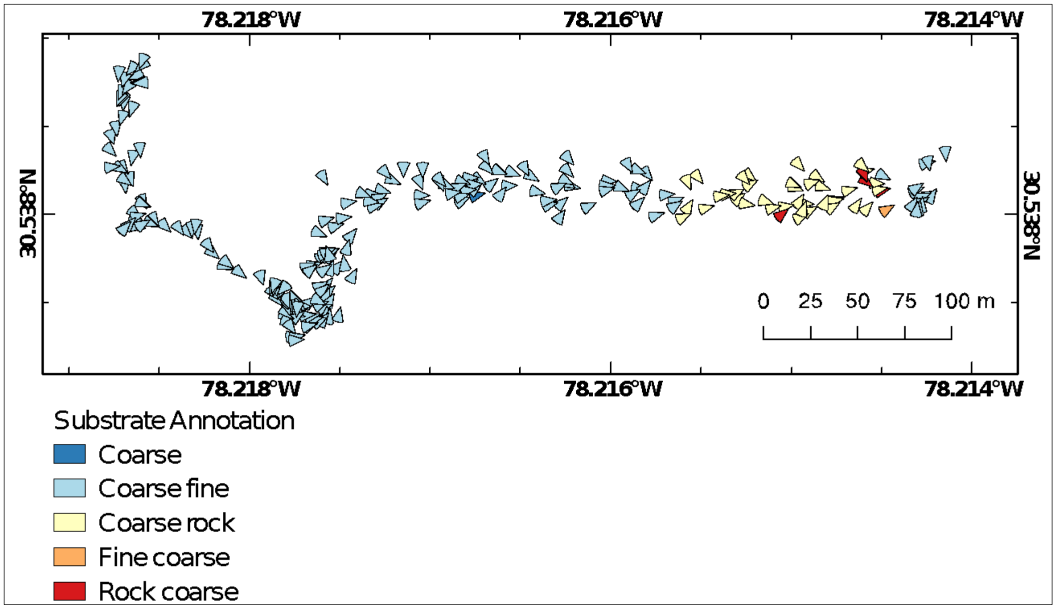

Figure 48. Viewsheds of seafloor imaged by ROV at time substrate annotation was made. Viewsheds are colored by Coastal and Marine Ecological Classification Standard (CMECS) substrate class.

4.4 Habitat Suitability Modeling

Background and Objectives:

Deep-sea corals have a broad but patchy distribution, and it requires substantial time and expense to explore and characterize their habitats. Because of this, models of species distribution are useful, if not essential, tools that provide comprehensive spatial information at the scale and extent needed to inform management and conservation of deep-sea coral habitat. Models allow us to predict coral extent, including potential habitat in areas that have not been explored. Predictive habitat models relate the actual occurrence of deep-sea corals from field surveys to a suite of potential environmental predictor variables. The modeled relationships can be used to assess, predict, and map the relative suitability (i.e., species habitat suitability) across a broad area of interest. Maps of the predicted habitat suitability for deep-sea corals have proven useful both to the ocean exploration and deep-sea coral science communities, as well as fishery management councils and other management and conservation planning bodies.

From 2011–2013 the NOAA National Centers for Coastal Ocean Science Marine Spatial Ecology Division developed a suite of predictive habitat models for deep-sea corals for the U.S. South Atlantic and Gulf of Mexico based on sparse preliminary data (Kinlan et al., 2013). These models represented most of the deep-sea coral taxa and groups of interest to the NOAA DSCRTP and the fishery management councils. However, one vulnerable and very long-lived taxon, the black coral *Leiopathes glaberrima*, was not modeled as part of this earlier effort because of insufficient reliable occurrence data. Further, no regional predictive habitat models for deep-sea corals had been developed for the U.S. Caribbean, although 14 years of benthic surveys had taken place there using an ROV.

Therefore, the primary objective of this study was to expand upon the existing predictive habitat models in the area of interest for SEDCI by developing models for *Leiopathes* in the Gulf of Mexico and U.S. South Atlantic and models for a broad range of deep-sea coral taxa or groups of interest in the U.S. Caribbean. SEDCI also funded a number of “data rescues” to support ongoing improvement and validation of these models, including a series of presence/absence models funded by BOEM (Goyert et al., 2021).

Approach:

Records of *L. glaberrima* occurrence (i.e., presence) were obtained from the NOAA National Database for Deep-Sea Corals and Sponges for the U.S. Gulf of Mexico and the U.S. South Atlantic Records were closely reviewed, and some errant records were flagged as described in Etnoyer et al., 2018. Predictive habitat models were fit using the maximum entropy (Maxent) modeling methods described in Etnoyer et al., 2018 and Kinlan et al., 2020.

Records of deep-sea coral occurrence were also obtained from the NOAA National Database for Deep-Sea Corals and Sponges for the U.S. Caribbean. Initial examination of the number and spatial distribution of these records in 2018 indicated that there were insufficient records to support development of reliable models. Consequently, an additional effort was undertaken to "rescue" records of deep-sea coral occurrence from benthic ROV surveys conducted by the U.S. Environmental Protection Agency (EPA) and NCCOS, led by Tim Battista with funding from NOAA Coral Reef Conservation Program. The objective of this effort was to annotate deep-sea coral occurrence from 100 additional ROV dives selected to provide spatial coverage across the U.S. Caribbean. Records from this effort were submitted to the NOAA National Database for Deep-Sea Corals and Sponges. In addition, records of deep-sea coral occurrence from recent OER-led ROV dives conducted from NOAA Ship *Okeanos Explorer* were also submitted to the National Database. With these additional records, predictive habitat models will be developed for a range of deep-sea coral taxa or groups of interest using the Maxent modeling methods described in Kinlan et al., 2020 and some advances (e.g., spatial cross-validation) to the modeling methods as described in Poti et al., 2020.

Significant Results to Date:

Areas with the highest likelihood of suitable habitat for *L. glaberrima* were predicted to occur on the continental slope at depths from 200–1,000 m in the northwestern Gulf of Mexico near the Flower Garden Banks region, in the northern Gulf of Mexico off Mississippi and Alabama, and on the southern part of the West Florida Slope (Figure 49). Depth, mean annual bottom temperature, and seafloor slope at 10 km scale were the most influential of the 13 environmental predictor variables included in the model. Additional details of the predictive habitat model for *L. glaberrima* in the U.S. Gulf of Mexico are described in Etnoyer et al., 2018. Although there were additional records of *Leiopathes* in the U.S. South Atlantic compared to the 2011–2013 modeling effort, there were still insufficient records to support a Maxent modeling. A model for *Leiopathes* using presence/absence records is expected to be part of an ongoing study funded by BOEM.

Records of deep-sea coral occurrence were annotated from ROV dives conducted over 14 years in the U.S. Caribbean (Table 7). These records have been submitted to the NOAA National Database for Deep-Sea Corals and Sponges and are presently 'in review by the NOAA DSCRTP. Predictive habitat models for a range of deep-sea coral taxa are in preparation.

Point of Contact:

Matthew Poti (matthew.poti@noaa.gov), CSS, Inc. in support of NOAA NCCOS MSE

References and document links:

Etnoyer PJ, Wagner D, Fowle HA, Poti M, Kinlan B, Georgian SE, Cordes EE. 2018. Models of habitat suitability, size, and age-class structure for the deep-sea black coral *Leiopathes* glaberrima in the Gulf of Mexico. Deep-Sea Research Part II 150:218–228.

Goyert HF, Bassett R, Christensen J, Coleman, H, Coyne M, Etnoyer PJ, Frometa J, Hourigan, TF, Poti M, Salgado EJ, Williams, B, Winship AJ. 2020. Characterizing spatial distributions of deep-sea corals and chemosynthetic communities in the US Gulf of Mexico through data synthesis and predictive modeling. New Orleans (LA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2021-027. 317 p

Kennedy, B.R.C., Cantwell, K., Sowers, D., Quattrini, A.M., Cheadle, M.J., McKenna, L. (2015). EX1502L3 Expedition Report- Océano Profundo 2015: Exploring Puerto Rico's Seamounts, Trenches, and Troughs. Office of Ocean Exploration and Research, Office of Oceanic &Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Rep. 2015-02-03, 93 p. doi.org/10.7289/V5NG4NM8

Kinlan BP, Poti M, Drohan AF, Packer DB, Dorfman DS, Nizinski MS. 2020. Predictive modeling of suitable habitat for deep-sea corals offshore the Northeast United States. Deep-Sea Research Part I 158:103229.

Kinlan B, Poti M, Etnoyer P, Siceloff L, Jenkins C, Dorfman D, Caldow C. 2013. U.S. Gulf of Mexico Deep Sea Coral Habitat Suitability Models — Digital Data Package [dataset]. Silver Spring (MD): U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service, National Centers for Coastal Ocean Science. Link here.

Poti M, Henkel SK, Bizzarro JJ, Hourigan TF, Clarke ME, Whitmire CE. Powell A, Yoklavich MM, Bauer L, Winship AJ, Coyne M, Gillett DJ, Gilbane L, Christensen J, Jeffrey CFG. 2020. Cross-Shelf Habitat Suitability Modeling: Characterizing Potential Distributions of Deep-Sea Corals, Sponges, and Macrofauna Offshore of the US West Coast. Camarillo (CA): US Department of the Interior, Bureau of Ocean Energy Management. OCS Study BOEM 2020-021. 267p.

Wagner D, Sowers D, Williams SM, Auscavitch S, Blaney D & Cromwell M (2018). EX1811 Expedition Report - Océano Profundo 2018: Exploring Deep-Sea Habitats off Puerto Rico and the U.S. Virgin Islands. Office of Ocean Exploration and Research, Office of Oceanic & Atmospheric Research, NOAA, Silver Spring, MD 20910. OER Expedition Report EX1811, 171 pp. doi: 10.25923/wc2n-qg29

Images, maps, graphs, other key figures:

Table 7. Datasets submitted to the NOAA National Database for Deep-Sea Corals and Sponges to support regional predictive habitat models in the U.S. Caribbean. NCCOS = NOAA National Centers for Coastal Ocean Science, EPA = U.S. Environmental Protection Agency, OER = NOAA Office of Ocean Exploration and Research.

Dataset	Principal Investigator	Institution	Number of Records	Status
NF-05-05	Battista	NCCOS	11	In Database
NF-06-03	Battista	NCCOS	129	In Database
NF-07-06	Battista	NCCOS	209	In Database
NF-08-04	Battista	NCCOS	269	In Database
NF-09-01	Battista	NCCOS	8	In Database
NF-11-01	Battista	NCCOS	TBD	In Review
NF-12-01	Battista	NCCOS	127	In Database
NF-13-01	Reiss	EPA	TBD	In Review
NF-13-02	Battista	NCCOS	647	In Database
NF-14-01	Battista	NCCOS	308	In Database
NF-15-01	Battista	NCCOS	TBD	In Review
EX-15-02	Kennedy	OER	303	In Database
NF-16-01	Battista	NCCOS	TBD	In Review
NF-18-04	Battista	NCCOS	4194	In Database
EX-18-11	Wagner	OER	1963	In Database
NF-19-01	Battista	NCCOS	2257	In Database

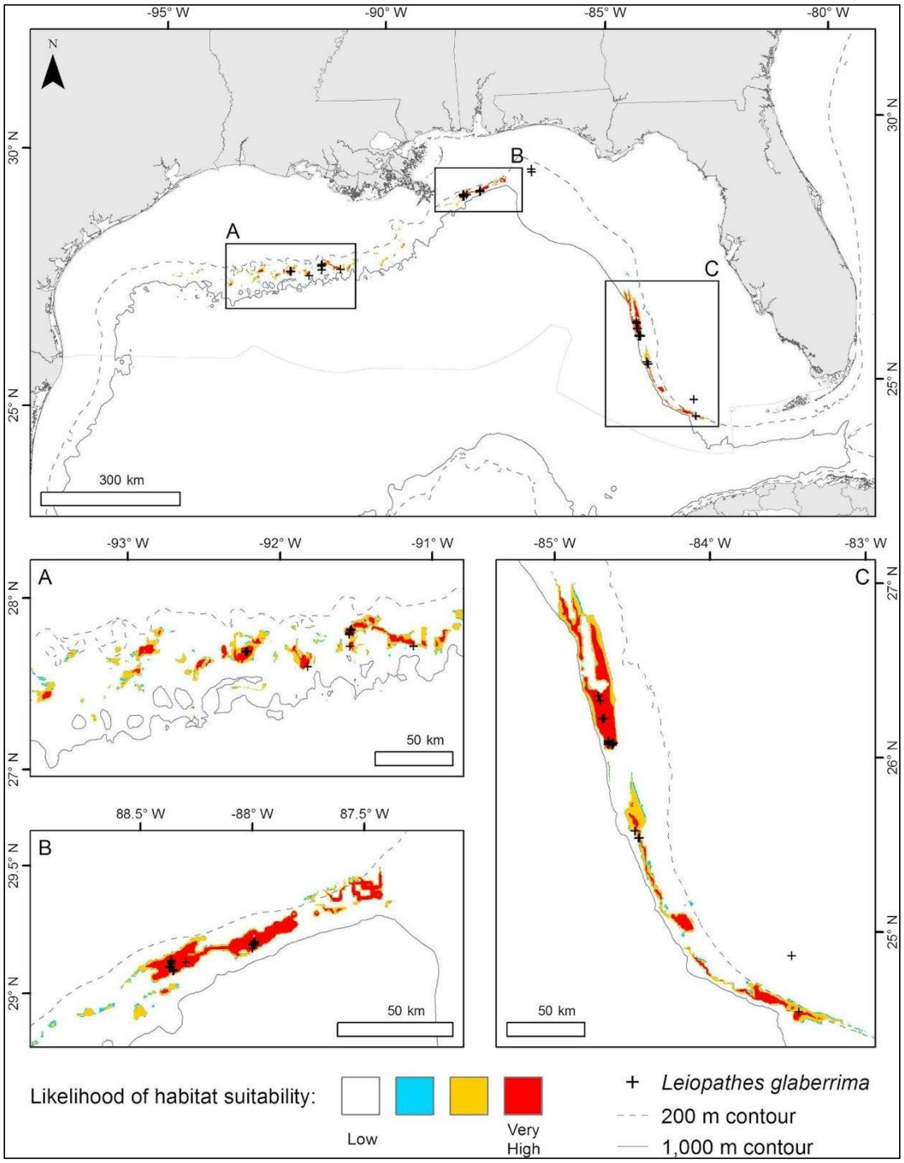

Figure 49. Records of *Leiopathes glaberrima* from the NOAA National Database for Deep-Sea Corals and Sponges overlaid on the predicted likelihood of habitat suitability from the predictive habitat model for *L. glaberrima* in the U.S. Gulf of Mexico and A) in the northwestern Gulf of Mexico, B) in the northern Gulf of Mexico, and C) on the West Florida Slope (from Etnoyer et al., 2018).

4.5 Data Mining of Existing Coral and Sponge Records

Background and Objectives:

Data mining of existing data records is a low-cost alternative to collecting new data and was identified as a top priority during the SEDCI science priorities workshop (Schull et al., 2016). The objective of this project was to access existing records at multiple institutions, and obtain deep-sea coral and sponge records that had not yet been submitted to the DSCRTP National Database of Deep-Sea Coral and Sponges. The purpose of the exercise is to update archives, increase the number of known observations, and support habitat suitability modeling efforts.

Approach:

SEDCI staff reached out to contact several field researchers who attended the planning workshop in order to identify relevant and available resources from past expeditions. Once these "untapped" coral and sponge records were identified, they were incorporated into statements of work in small grants through NOAA Cooperative Institutes, and small subcontracts through CSS, Inc. Data were reformatted and prepared for submission to the NOAA National Database for Deep Sea Corals and Sponges, based upon the NOAA DSCRTP data management standards (see Hourigan et al., 2015). Records of interest included all habitat forming deep-sea corals (Scleractinia, Octocorallia, Antipatharia, Pennatulacea, Stylasteridae) and sponges (Porifera). Key parameters of interest included metadata from the institution of origin, vessel name, vehicle name, date, time of observation, dive number, depth, longitude, latitude, taxonomic identification to lowest taxa possible, abundance (as counts, density or cover), habitat type, and other appropriate notes on observation or samples.

Significant Results to Date:

Over 45 datasets, resulting in 42,957 records from rescued data, have been analyzed and submitted to the DSCRTP national database in the course of this data mining project. NOAA Flower Garden Banks National Marine Sanctuary analyzed three historic cruises and contributed a black coral dataset from thesis work that was partially funded by SEDCI. Gray's Reef National Marine Sanctuary contributed a Masters thesis partially funded by SEDCI and a dataset from 2010. An ongoing NOAA project in the Caribbean submitted nine datasets spanning 2005-2019. Through our cooperative institute partnerships, Harbor Branch Oceanographic Institute at Florida Atlantic University contributed data from 24 cruises ranging from 1988-2017. Florida State University and Nova Southeastern University contributed data from five past cruises, as well as two manuscripts based on the fieldwork during those cruises. Finally, three datasets that originated during the DWH damage assessment were submitted in 2018.

Points of Contact:

Rachel Bassett (rachel.bassett@noaa.gov) CSS, Inc., in support of NOAA NCCOS MSE
Peter Etnoyer (peter.etnoyer@noaa.gov) NOAA NCCOS MSE

Additional Collaborators:

Charles Fisher, Pennsylvania State University; Charles Messing and Brian Walker, Nova Southeastern University; Emma Hickerson, NOAA FGBNMS; Ian MacDonald, Florida State University; John Reed and Stephanie Farrington, Harbor Branch Oceanographic Institute, Florida Atlantic University; Leslie Wickes, Thrive Blue Consulting; Sandra Brooke, Florida State University; Stephanie Sharuga, BOEM; Tim Battista, NOAA NCCOS; George Sedberry, NOAA Gray's Reef NMS

References and document links:

Hourigan, T. F., P. J. Etnoyer, R. P. McGuinn, C. Whitmire, D.S. Dorfman, M. Dornback, S. Cross, D. Sallis. 2015. An Introduction to NOAA's National Database for Deep-Sea Corals and Sponges. NOAA Technical Memorandum NOS NCCOS 191. 27 pp. Silver Spring, MD.

Schull, J., Etnoyer P. J. & Wagner D. (2016) NOAA Deep Sea Coral Research and Technology Program Southeast Initiative Priority Scoping Workshop Report, November 18-20, St. Petersburg, Florida. NOAA Technical Memorandum. NMFS-SEFSC-695, 59pp.

Publications from project:

Walker, Brian K., Charles Messing, Jana Ash, Sandra Brooke, John K. Reed, Stephanie Farrington, Regionalization of benthic hard-bottom communities across the Pourtalès Terrace, Florida, Deep Sea Research Part I: Oceanographic Research Papers, Volume 172, 2021, 103514, ISSN 0967-0637, https://doi.org/10.1016/j.dsr.2021.103514

Yeckley, Sean Paul. (2017) "Temporal trends in abundance and habitat preferences of deep reef fishes off the coast of South Carolina, USA." Masters thesis at Savannah State University. hdl.handle.net/11286/620752

5. New Coral and Sponge Records

NOAA's Deep Sea Coral Research and Technology Program compiles, curates, and makes publicly accessible a National Database of biogeographic data and information on deep-sea corals and sponges (Hourigan et al., 2015; McGuinn et al., 2020). The database is accessible through DSCRTP's Data Portal (**https://deepseacoraldata.noaa.gov/**), which serves as a major resource for both scientists and managers.

As shown in Figures 50-53 & 58, the number of deep-sea coral and sponge data records available in the region grew dramatically as a result of SEDCI research operations. Most ROV and towed camera surveys conducted by SEDCI have already been analyzed, submitted to the National Database, and available from the Data Portal. As of July 2021, 19,797 new records of deep-sea corals and sponges from ten new data sets have been added to the database. The majority of these records include the associated images. Analysis of drop camera surveys in Puerto Rico is ongoing and will provide additional new records in areas of high interest to the deepwater fishing community. In addition to this new research, SEDCI data rescue efforts have added an additional 48 datasets and 47,506 records from older surveys.

A primary focus of the DSCRTP data efforts is to inform fishery management council spatial management measures to protect deep-sea corals and the habitats they provide (see Section 7). Figures 50-53 show the distribution of existing and new deep-sea coral and sponge records in relation to areas protected from seafloor trawling or each fishery management council region in the Southeast U.S. This information has improved information available on the status of these resources within fishery-restricted zones, as well as providing new information on coral and sponge habitats outside these zones. Especially notable in Figure 53 is how dramatically data records in the Caribbean region grew during SEDCI (gray bars).

Point of Contact:

Robert McGuinn (robert.mcguinn@noaa.gov), Northern Gulf Institute, in support of NOAA NCEI

References and document links:

Hourigan, T. F., P. J. Etnoyer, R. P. McGuinn, C. Whitmire, D.S. Dorfman, M. Dornback, S. Cross, D. Sallis. 2015. An Introduction to NOAA's National Database for Deep-Sea Corals and Sponges. NOAA Technical Memorandum NOS NCCOS 191. 27 pp. Silver Spring, MD. HERE

McGuinn RP, Hourigan TF, Cross SL, Dornback M, Etnoyer PJ, Sallis DE, Coleman HM (2020) NOAA's National Database for Deep-Sea Corals and Sponges: 2020 Status Update. NOAA Tech Memo NMFS-OHC-007 56 pp. HERE

A full detailed report of the current database holdings for the SEDCI project is available HERE

Images, maps, graphs, other key figures:

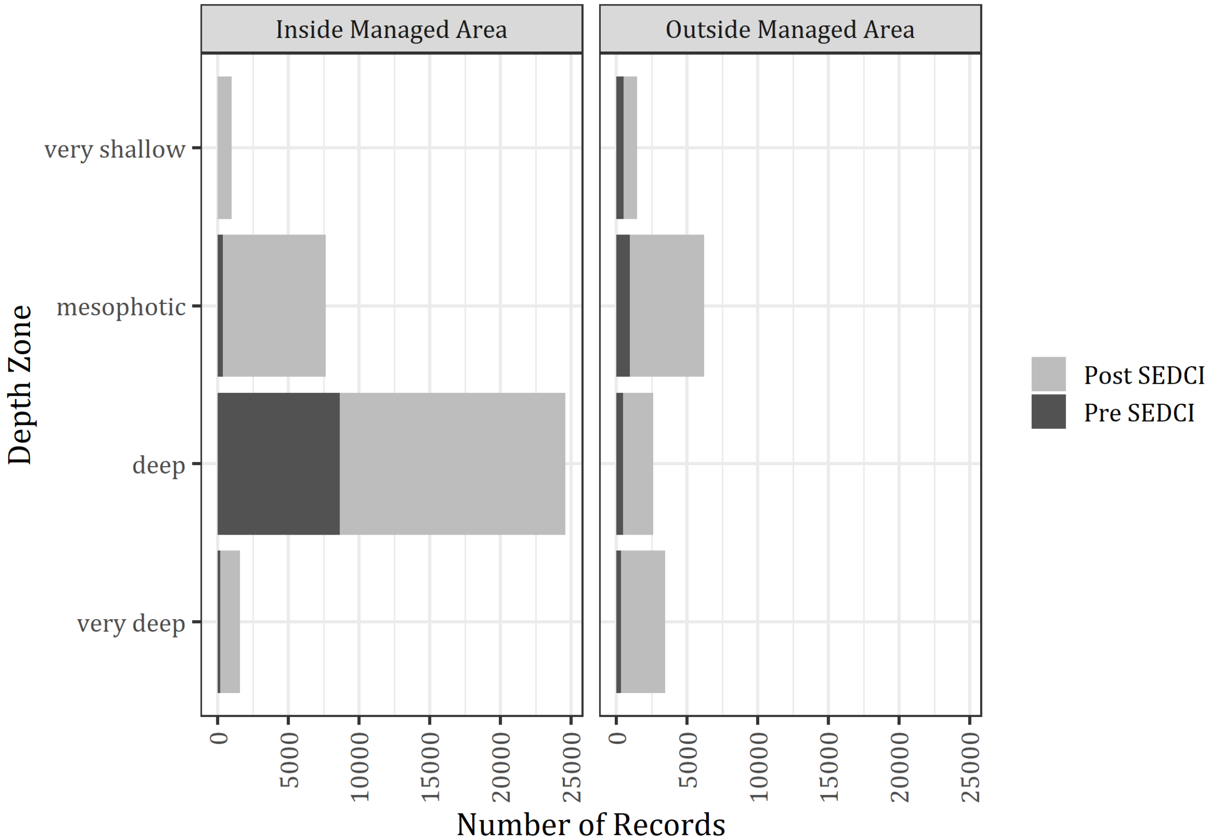

Figure 50. Number of deep-sea coral and sponge records in the South Atlantic Fishery Management Council region added to the National Database before SEDCI began in 2016 (dark bars), and records added since through SEDCI research and data mining operations (between 2016-2021, light gray bars). Bars are split between records located within areas protected from seafloor trawling (left side), and areas open to fishing (right side). Records are also classified as very shallow (<50m depth), mesophotic (50-200m), deep (Upper Bathyal: 201-800m), and very deep (>800m).

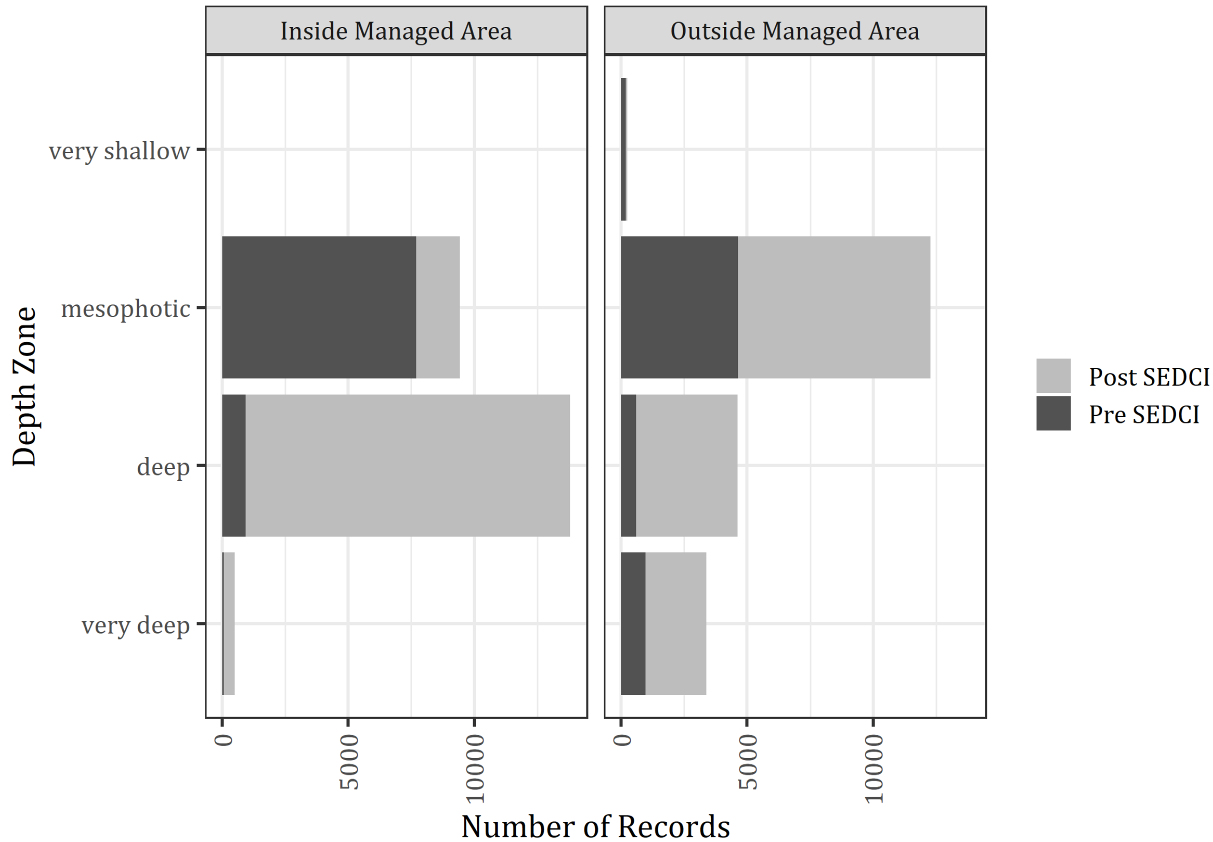

Figure 51. Number of deep-sea coral and sponge records in the Gulf of Mexico Fishery Management Council region added to the National Database before SEDCI began in 2016 (dark bars), and records added since through SEDCI research and data mining operations (between 2016-2021, light gray bars). Bars are split between records located within areas protected from seafloor trawling (left side), and areas without trawling restrictions (including HAPCs without regulations, right side). Records are also classified as very shallow (<50m depth), mesophotic (50-200m), deep (Upper Bathyal: 201-800m), and very deep (>800m).

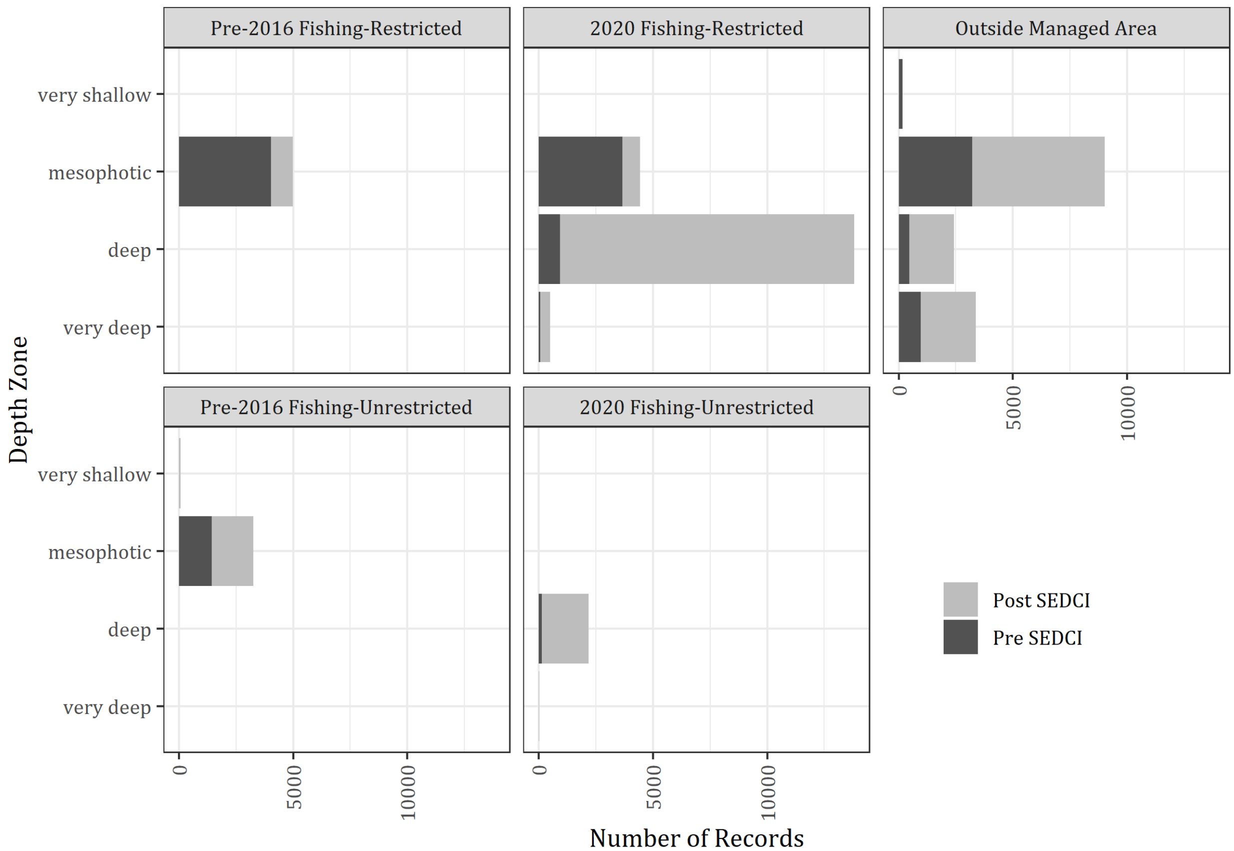

Figure 52. Number of deep-sea coral and sponge records in the Gulf of Mexico Fishery Management Council region added to the National Database before SEDCI began in 2016 (dark bars), and number of records added after SEDCI began research and data mining operations (between 2016-2020, light gray bars). Plots are divided according to managed area status, including categories for HAPCs (both with fishing regulations and without) that were already in place by 2016 ("Pre-2016 Fishing-Restricted" and "Pre-2016 Fishing-Unrestricted," respectively), HAPCs (both with fishing regulations and without) that were implemented in 2020 ("2020 Fishing-Restricted" and "2020 Fishing-Unrestricted," respectively), and outside managed areas. Records are classified as very shallow (<50m depth), mesophotic (50-200m), deep (Upper Bathyal: 201-800m), and very deep (>800m). Prior to 2020 there were no deep-sea (>200 m) HAPCs protected from bottom fishing impacts in the Gulf of Mexico. The observations provided by SEDCI (light grey bars) informed the recent HAPC designations.

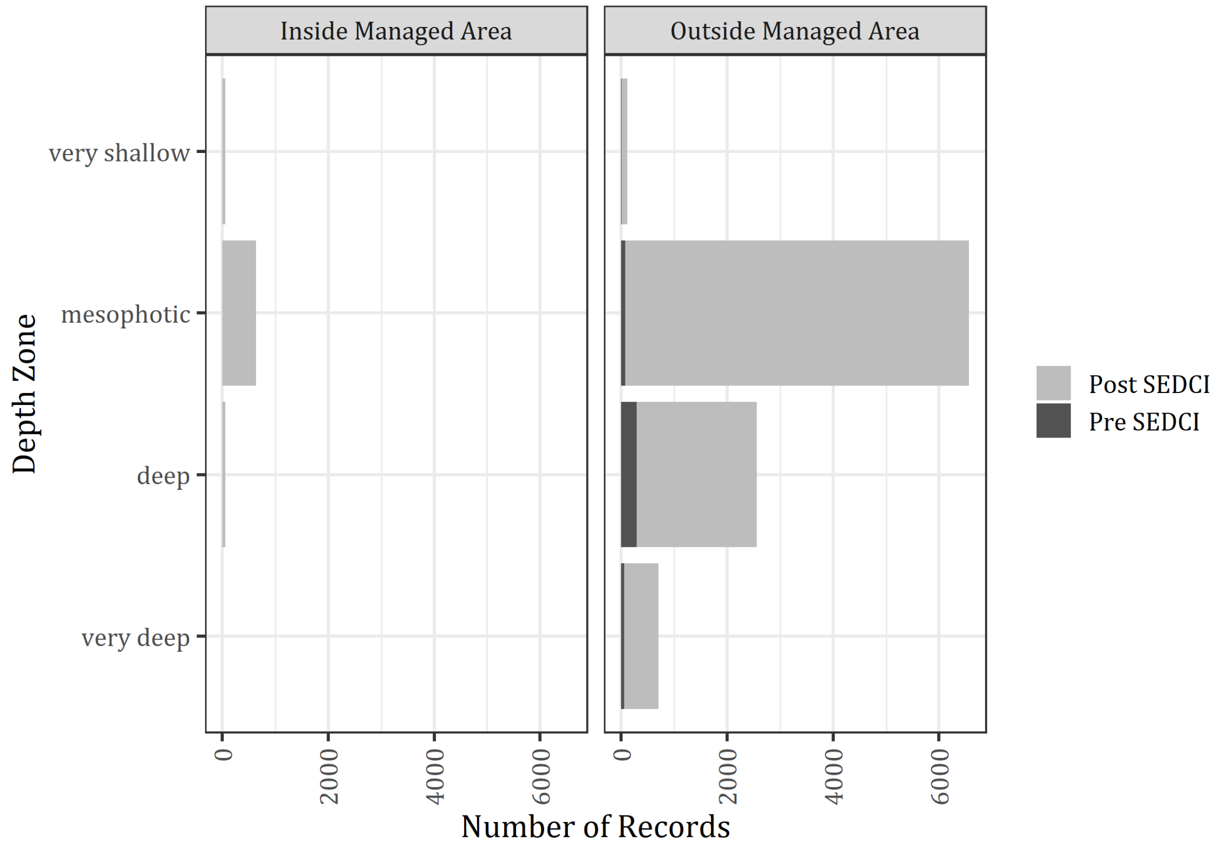

Figure 53. Number of deep-sea coral and sponge records in the Caribbean Fishery Management Council region added to the National Database before SEDCI began in 2016 (dark bars), and records added after SEDCI began research and data mining operations (between 2016-2020, light gray bars). Records are classified as very shallow (<50m depth), mesophotic (50-200m), deep (Upper Bathyal: 201-800m), and very deep (>800m). Most managed areas protected from bottom-fishing impacts in U.S. Caribbean waters are relatively shallow (left side).

6. Education and Outreach

6.1 Student Engagement

Students represent the next generation of ocean scientists and managers, and embody NOAA's hope and aspirations for sustainable management of coastal resources. Therefore, student participation in scientific projects, and aboard research cruises, was an important and exciting part of SEDCI project planning. SEDCI assisted in the support of 45 students from high school to PhD students from over 20 institutions (Figure 54). Of these, 36 students were able to participate on research cruises in the Southeast U.S. and the Gulf of Mexico (Table 8 and Figure 55), and 11 students participated in small projects (Table 9). To date, six Masters projects resulted from SEDCI support and two Hollings Scholars completed projects that were mentored by SEDCI scientists.

In addition to projects and research cruises, SEDCI contributed to a brief two-day deep-sea coral taxonomy and morphology workshop held in conjunction with the NOAA Center for Coastal and Marine Ecosystems meeting in Charleston. Among the participants were two graduate students from University of Texas Rio Grande Valley (UTRGV). During the workshop, participants were taught to use diagnostic characteristics to distinguish various species of black and gorgonian corals. The graduate students were able to process their own deep-sea coral samples from Flower Garden Banks and UTRGV with light and scanning electron microscopy (SEM).

Drop-in "watch parties" were hosted in the Charleston NOAA ECC at Hollings Marine Laboratory during two NOAA Ship *Okeanos Explorer* cruises. The public was invited to come to the ECC and watch the dives in real time. Partners at Fort Johnson campus include College of Charleston, Medical University of South Carolina, and National Institutes for Standards and Technology. The College's Research Experiences for Undergraduates program enabled two dozen students to view a live seafloor survey using telepresence. NOAA Deep Coral Ecology Lab and OER staff were there to give a tour of the ECC and an overview of the exploration process and technology used by NOAA Ship *Okeanos Explorer*. These watch parties were attended by three different professors with their classes, as well as individual students, all from College of Charleston (Figure 56). One high school student drove from Georgetown, South Carolina to participate (Figure 57). The ROV pilots on board the ship recognized this student by name, as well as the various institutions represented by individuals who attended the watch party.

Project Participants:

- 1 post-doc - Erin Easton (UTRGV-Hicks Lab) funded by Cooperative Science Centers through the NOAA Center for Coastal and Marine Ecosystems
- 2 Hollings Scholars - Morgan Will (Nova Southeastern-Messing Lab) and Laura Anthony (Western Washington University)
- 6 Masters students - Marissa Nuttall (Texas A & M - Hickerson Lab), Jake Freeman (Mississippi State University - Skarke Lab), Kate Overly (University of Florida - Andy David Lab), Zach Proux (College of Charleston - Etnoyer Lab), Travis Sterne (Texas A & M - Hickerson Lab), Sean Paul Yeckley (Savannah State University - Sedberry Lab)
- 20 undergraduate students engaged in telepresence through the Research Experience for Undergraduate program funded by the National Science Foundation (Bob Podolsky, College of Charleston)
- 2 high school students - Kamaja Elmore (Georgetown High School) and Allie Battista (Silver Spring High School)

Publications from project:

Freeman, J. (2022) Geospatial analysis of deep-sea benthic environments through application of the Coastal and Marine Ecological Classification Standard to ROV video data. Masters Thesis: Mississippi State University, Mississippi State, MS, USA. *Anticipated*

Nuttall, M.F., Opresko, D.M. and Hickerson, E.L., 2016. Validation of Image-Based Species Identifications of Black Corals (Order Antipatharia) on Mesophotic Rocks. *Gulf of Mexico Science*, *33*(1), p.3. doi.org/10.18785/goms.3301.03

Overly, K.E. V.L. Lecours. 2021 (in prep). Mapping Queen Snapper (*Etelis oculatus*) Suitable Habitat in Puerto Rico Using Ensemble Species Distribution Modeling.

Proux, Zachary Samuel (2018) Assessing the Relationship between Geomorphology and Deep-Sea Megafaunal Communities on the West Florida Escarpment." Masters thesis at College of Charleston. repository.library.cofc.edu/handle/123456789/3720

Sowers, Derek C., "Utilizing Extended Continental Shelf (ECS) and Ocean Exploration Mapping Data for Standardized Marine Ecological Classification of the U.S. Atlantic Margin" (2020). *Doctoral Dissertations*. 2556. https://scholars.unh.edu/dissertation/2556

Sterne, TK, Retchless, D, Allee, R, Highfield, W. Predictive modelling of mesophotic habitats in the north-western Gulf of Mexico. *Aquatic Conserv: Mar Freshw Ecosyst*. 2020; 30: 846–859. doi.org/10.1002/aqc.3281

Will, Morgan. Diversity and Abundance of Deep-Sea Corals and Sponges in the Bathyal Terrain of West Florida Escarpment. NOAA Mission Goal: Healthy Oceans. Poster presented at the Ocean Sciences Meeting, Feb 16-21, 2020, San Diego, CA.

Yeckley, Sean Paul. (2017) "Temporal trends in abundance and habitat preferences of deep reef fishes off the coast of South Carolina, USA." Masters thesis at Savannah State University. hdl.handle.net/11286/620752

Images, maps, graphs, other key figures:

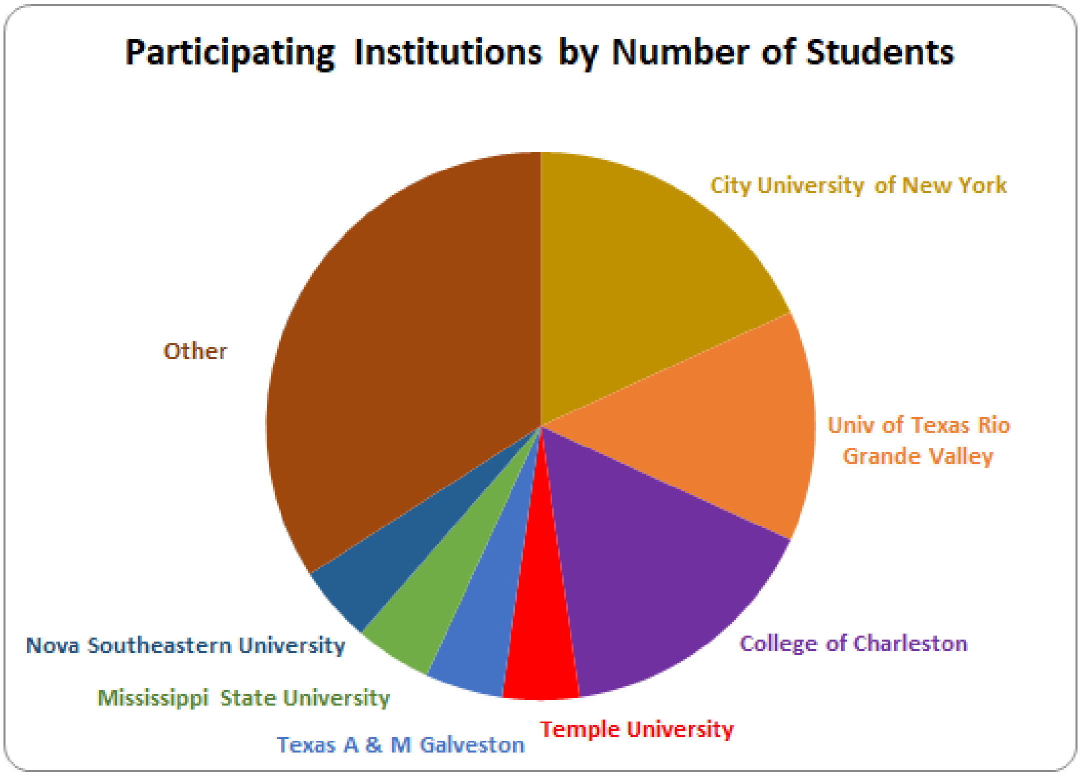

Figure 54. Institutions participating in SEDCI activities by proportion of students. "Other" is a category where n=1 student at these institutions: University of South Florida, Nelson Mandela University, Florida A & M, Bethune-Cookman University, University of Maryland, University of Maine, University of Georgia, University of California Santa Cruz, University of Louisiana, Harvey Mudd College, University of Florida - Gainesville, James Madison University, Western Washington University, Savannah State University, Georgetown High School, Silver Spring High School.

Table 8. Student participants on shipboard research cruises and their affiliations.

Year	Vessel	Student	Affiliation	Mentor
2016	*Manta* DFH 30	Travis Sterne	Texas A & M Galveston	Emma Hickerson
2016	*Manta* DFH 30	Nicole Bellaflores-Meija	City University of New York	Mercer Brugler
2016	*Manta* DFH 30	Sheila Moaleman	City University of New York	Mercer Brugler
2016	*Manta* DFH 30	Elissa Connolly-Randazzo	Univ of Texas Rio Grande Valley	David Hicks
2016	*Manta* DFH 30	Linda Jordan	Univ of Texas Rio Grande Valley	David Hicks
2016	*Pisces* PC1605	Shelby Bowden	College of Charleston	Leslie Sautter
2016	*Pisces* PC1605	William Hefner	College of Charleston	Leslie Sautter
2017	*Nancy Foster* NF1708	John Gray	University of South Florida	David Naar
2017	*Nancy Foster* NF1708	Zoleka Filander	Nelson Mandela University	Steve Cairns
2017	*Nancy Foster* NF1708	Zach Proux	College of Charleston	Peter Etnoyer
2017	*Nancy Foster* NF1708	Rachel Fein	College of Charleston	Leslie Sautter
2017	*Nancy Foster* NF1708	Evalynn Barbare	College of Charleston	Leslie Sautter
2017	*Nancy Foster* NF1708	Tyler Hansberry	Florida A & M	Larry Robinson
2017	*Nancy Foster* NF1708	Mallory Brooks	Bethune - Cookman University	Audrey Trotman
2017	*Manta* DFH 32	Travis Sterne	Texas A & M Galveston	Emma Hickerson
2017	*Manta* DFH 32	Nadia Alomari	City University of New York	Mercer Brugler
2017	*Manta* DFH 33	Travis Sterne	Texas A & M Galveston	Emma Hickerson
2017	*Manta* DFH 33	Colin Joseph	City University of New York	Mercer Brugler
2017	*Manta* DFH 33	Chelsea Pavliska	University of Texas Rio Grande Valley	David Hicks
2017	*Manta* DFH 33	Samantha Goldman	University of Maryland - College Park	Mercer Brugler
2018	*Pisces* PC1802	Elizabeth Gugliotti	College of Charleston	Peter Etnoyer
2018	*Nancy Foster* NF1804	Allie Battista	Silver Spring High School	Tim Battista
2018	*Okeanos* EX1806	Kamaja Elmore	Georgetown High School	Kim Finley
2018	*Manta* DFH35	Rachel Ross	City University of New York	Mercer Brugler
2018	*Manta* DFH35	Raven Johnson	City University of New York	Mercer Brugler
2018	*Manta* DFH35	Grace McDermott	University of Maine	Emma Hickerson
2018	*Atlantis* AT-41	Zach Proux	College of Charleston	Peter Etnoyer
2018	*Atlantis* AT-41	Alexis Weinnig	Temple University	Erik Cordes
2018	*Atlantis* AT-41	Ryan Gasbarro	Temple University	Erik Cordes
2018	*Atlantis* AT-41	Hannah Choi	University of Georgia	Samantha Joye
2018	*Atlantis* AT-41	Natasha Vokhshoori	University of California Santa Cruz	Matthew McCarthy
2018	*Manta* DFH37	Caroline Vill	College of Charleston	Peter Etnoyer
2018	*Manta* DFH37	Katherine Parra	City University of New York	Mercer Brugler
2018	*Manta* DFH37	Naomi Chery	City University of New York	Mercer Brugler
2018	*Manta* DFH37	Chelsea Pavliska	University of Texas Rio Grande Valley	David Hicks
2018	*Manta* RESTORE2	Emma Saso	Harvey Mudd College	Andrea Quattrini
2018	Various	Kate Overly	University of Florida - Gainesville	Andy David
2019	*Nancy Foster* NF1909	Hannah Choi	University of Georgia	Samantha Joye
2019	*Nancy Foster* NF1909	Alex Davis	Nova Southeastern University	Tracey Sutton

Table 9. Student participants in small projects and their affiliations.

Year	Project	Student	Affiliation	Status
2016	Validation of image-based species identifications of black corals (Order Antipatharia) on mesophotic reefs	Marissa Nuttall	Texas A & M Galveston	Masters student
2016-2017	Temporal trends in abundance and habitat preferences of deep reef fishes off the coast of South Carolina, USA.	Sean Paul Yeckley	Savannah State University	Masters student
2016-2018	FGBNMS geospatial analysis	Travis Sterne	Texas A & M Galveston	Masters student
2017-2018	Characterization of the W. FL shelf	Zach Proux	College of Charleston	Masters student
2017-2020	Cooperative research - Queen Snapper habitat classification	Kate Overly	University of Florida - Gainesville	Masters student
2018-2020	FGBNMS data analysis and photo ID guide	Raven Blakeway	Texas A & M Galveston	Doctoral student
2019	Density and abundance of bathyal corals and sponges on the West Florida shelf	Morgan Will	Nova Southeastern University	Hollings Scholar – Undergraduate
2019	Relationship between octocoral gardens, substrate type and depth in the Channel Islands NMS	Jordan Penn	Millersville University	Research Experiences for Undergraduates Program - Undergraduate
2019	Genetic analysis of deep corals	Erin Easton	University of Texas Rio Grande Valley	Post-doctoral fellow
2019-2020	Impact of anthropogenic debris on deep-sea coral and sponge habitat	Laura Anthony	Western Washington University	Hollings Scholar - Undergraduate
2020	CMECS geospatial analysis and Python script	Jake Freeman	Mississippi State University	Undergraduate then Masters student

Figure 55. Students from four institutions aboard the NF1708 leg 2 cruise. From left to right, top row: Zach Proux-College of Charleston, Zoleka Filander-Nelson Mandela University, Rachel Bassett-NOAA affiliate, Mallory Brooks-Bethune-Cookman University, Evalynn Barbare-College of Charleston, Rachel Fein-College of Charleston, Chip Collier-South Atlantic Fisheries Management Council, bottom row: Katie Geddes-NOAA affiliate, Scott Cross-NOAA NESDIS, Daniel Wagner-NOAA affiliate, Tyler Hansberry-Florida A &M, Leah Fine-NOAA affiliate.

Figure 56. Students from College of Charleston (standing left) with SEDCI Lead Scientist Peter Etnoyer (standing right) in Charleston's "pop-up" Exploration Command Center during a NOAA Ship *Okeanos Explorer* watch party at Hollings Marine Laboratory. Photo courtesy of Bob Podolsky, College of Charleston.

Figure 57. Kamaja Elmore, a Georgetown High School student, drove from Georgetown, South Carolina to Charleston, South Carolina to participate in a live viewing of a dive from the *Okeanos Explorer* cruise EX1806 in the Hollings Marine Lab Exploration Command Center.

6.2 Outreach Activities and Events

Below is a brief description of the outreach and education events sponsored by SEDCI. There were outreach events targeted to the general public, students, the deep-sea community and within the SEDCI community.

The NCCOS Deep Coral Ecology Laboratory (DCEL) in Charleston, SC opened the Hollings Marine Lab Exploration Command Center to students and colleagues during live dives of NOAA Ship *Okeanos Explorer*. Pizza was provided at one such "party" and during these events there was a DCEL member and an OER staff member available to talk about the dives and answer questions. Also present were NOAA representatives who were creating live annotations while the attendees looked on. Professors from College of Charleston brought entire classes to observe the dives during these "watch parties."

A live event was hosted aboard NOAA Ship *Pisces* with the North Carolina Museum of Natural Sciences during the PC1704 cruise in 2017. The cruise was also featured on an education website hosted by the Museum.

SEDCI staff acted as NOAA representatives during live NOAA Ship *Okeanos Explorer* dives at the South Carolina Aquarium during two different expeditions. The staff handed out one-page flyers about the cruise and about NOAA, gave out NOAA pens and stickers, greeted attendees and answered questions during the dive.

DCEL held a two-day workshop on the taxonomy and morphological identification of deep-sea corals in conjunction with the NOAA Center for Coastal and Marine Ecosystems annual meeting in Charleston, SC. The workshop was attended by graduate students from the University of Texas Rio Grande Valley. Students obtained classroom instruction on the diagnostic characters that distinguish various species of black and gorgonian corals. The students also obtained hands-on experience in processing deep-sea coral specimens for light and scanning electron microscopy with their own samples.

A NOAA outreach video was created on SEDCI cruise NF-17-08 in the Gulf of Mexico by Ralf Mayer of Green Fire Productions. This video, Living in the Dark, can be found on the NOAA institutional repository.

NCCOS news stories outlining the highlights of SEDCI projects in 2018 and 2019 were written and submitted for online access in the NOAA institutional repository.

Articles about SEDCI accomplishments were sent to Deep Sea Life Newsletter with an overview of SEDCI and different project highlights throughout the initiative.

7. Informing Conservation and Managed Areas

Background:

Deep-sea corals and sponges in the U.S. South Atlantic, Gulf of Mexico, and Caribbean Fishery Management Council regions face a number of threats, depending on prevalent regional activities such as seafloor trawling, longline fishing, oil and gas operations, pipeline and cable installations, etc. (see SEDCI Science Plan, Schull et al., 2016, for more information). Some threats can be ameliorated by fishing restrictions, and others can be addressed by Essential Fish Habitat designation, both of which are within the councils' power to delineate. National marine sanctuaries may also complement fishing restrictions by prohibiting destructive gear types or access to certain areas to fishing, and other types of seafloor disturbance, such as anchoring, or discharges, such as wastewater.

In the greater Southeast U.S. region, fishery management councils and sanctuaries have been protecting deep-sea corals and sponges in specific areas for decades. The South Atlantic FMC began identifying important habitat and banning seafloor-contact fishing in Oculina Bank in 1984. Since then, it has prohibited various types of fishing gear from sixteen other deep-sea areas, covering 65,000 sq km. These areas are protected as Coral Habitat Areas of Particular Concern (Coral HAPCs), Marine Protected Areas, and Spawning Special Management Zones. The South Atlantic FMC has also expanded some of these areas years after establishment, based on updated information. The Gulf of Mexico FMC also protected the region's first HAPC from seafloor-contact fishing in 1984, and since then has designated seafloor-contact fishing restrictions across 5,000 sq km. These protections span ten HAPCs and marine reserves established before SEDCI, as well as 13 new HAPCs with regulations and eight HAPCs without regulations that were approved by the Gulf of Mexico FMC in 2018, with support from SEDCI. Flower Garden Banks National Marine Sanctuary, covering 145 sq km in the northwest Gulf of Mexico, was protected from activities such as anchoring and marine discharges in 1992, and prohibits gear types that cause significant bottom disturbance. Finally, the Caribbean FMC protected the first of its eight areas restricting all seafloor-contact fishing in 1999. The total deep seafloor area protected in the region is 1,640 sq km.

Approach:

Data collected during the first South Atlantic Deep-sea Coral Initiative (2009-2011) supported delineation of Coral HAPC boundaries implemented in 2010, as well as expansions in 2015. While only one ROV dive was conducted in the Gulf of Mexico as part of the first initiative, information collected from the dive informed the proposal of a HAPC off Western Florida (Schull et al., 2016). At the start of SEDCI in 2016, the main priorities of the South Atlantic FMC were mapping unexplored areas of interest to the South Carolina and Southeast Florida golden crab fisheries, studying biological and ecological aspects of deep-sea coral ecosystems in Coral HAPCs, and better understanding fishing effort in these areas (Schull et al., 2016). The Gulf of Mexico FMC prioritized mapping and surveys to support evaluation of HAPC proposals, and requested information inside and just outside proposed areas, particularly along the West Florida Shelf. Also, the Flower Garden Banks National Marine Sanctuary requested SEDCI funds to support gathering information to evaluate five alternative expansion proposals. For this initiative, the Caribbean FMC prioritized information to support marine protected area monitoring, deep-sea species identifications, habitat mapping, and deep-sea coral exploration near fish spawning aggregations.

Significant Results to Date:

Research, exploration, and data analysis conducted as part of SEDCI have already begun to inform council and sanctuary management decisions across the greater Southeast U.S. Site characterization reports from SEDCI-funded field surveys will be made available on NOAA's Deep Sea Coral Research and Technology Program Web Portal at deepseacoraldata.noaa.gov. Selected video and still images collected as part of SEDCI were annotated for the presence of coral and sponge taxa. These annotations were submitted to the National Database for Deep-sea Corals and Sponges available at deepseacoraldata.noaa.gov, following guidance provided by the DSCRTP. Submissions included both annotations of older imagery as well as newly collected. Figure 58 shows the distribution of existing and new deep-sea coral and sponge records and areas protected from bottom trawling for the region.

The first fishing restrictions supported in part by SEDCI data were approved by the Gulf of Mexico FMC in June 2018 and implemented by NOAA in November 2020 (purple areas in Figure 58). Within these 13 new HAPCs that gained seafloor fishing restrictions and eight HAPCs that were created without restrictions, SEDCI research increased the number of data records by approximately 25% overall. In the West Florida Wall HAPC, an area of particular interest to the Gulf of Mexico FMC due to significant coral aggregations, SEDCI surveys increased the known coral and sponge records by 4.5 times. Surveys in this area informed the FMC’s decision to combine three small proposed protections into one significantly larger and more effective conservation area. Partially due to SEDCI findings in the areas of interest, the FMC designated HAPCs in deep water, where very little protection existed before the Initiative (see Figures 51, 52).

The data and observations contributed through our exploration and annotation will continue to inform council and sanctuary management decisions in the greater Southeast U.S. region for years to come. For example, the South Atlantic FMC plans to discuss expanding the Stetson-Miami Terrace Deepwater Coral HAPC (see the large gray area in the South Atlantic in Figure 58) according to new mapping information and deep-sea coral and sponge records discovered on the Blake Plateau.

The Gulf of Mexico FMC also intends to begin planning another amendment to the Coral and Coral Reefs Fishery Management Plan in 2021 to address areas that were not incorporated into 2020 protections, particularly in the Flower Garden Banks area. Data and observations contributed by SEDCI have built on existing information to identify high density and nationally significant coral and sponge communities, inventory marine debris, and develop predictive habitat models for resources managers and the Sanctuary Advisory Council. The substantial progress made by SEDCI-sponsored research informed and refined the Flower Garden Banks National Marine Sanctuary proposed boundary expansion, and will support BOEM’s reassessment of the biological features stipulation. These efforts also resulted in the discovery of a new species of black coral, *Distichopathes hickersonae*, and several other potential new species in Sanctuary waters.

The Caribbean FMC will use SEDCI-derived taxonomic deep-sea coral information, species abundance and diversity, and forthcoming habitat suitability models (made possible by virtue of SEDCI data) in future decision-making. The FMC is planning to use these data to inform Essential Fish Habitat boundary delineation and possibly invoke the Magnuson-Stevens Act's Deep Sea Coral Discretionary Authority (Section 303(b)(2)) to protect these habitats independently from their benefits to fisheries.

Points of Contact:

Heather Coleman (heather.coleman@noaa.gov), NOAA Fisheries
Tom Hourigan (tom.hourigan@noaa.gov), NOAA Fisheries

References and document links:

Schull J, Etnoyer PJ & Wagner D (2016) NOAA Deep Sea Coral Research and Technology Program Southeast Initiative Priority Scoping Workshop Report, November 18-20, St. Petersburg, Florida. NOAA Technical Memorandum. NMFS-SEFSC-695, 59pp.

Images, maps, graphs, other key figures:

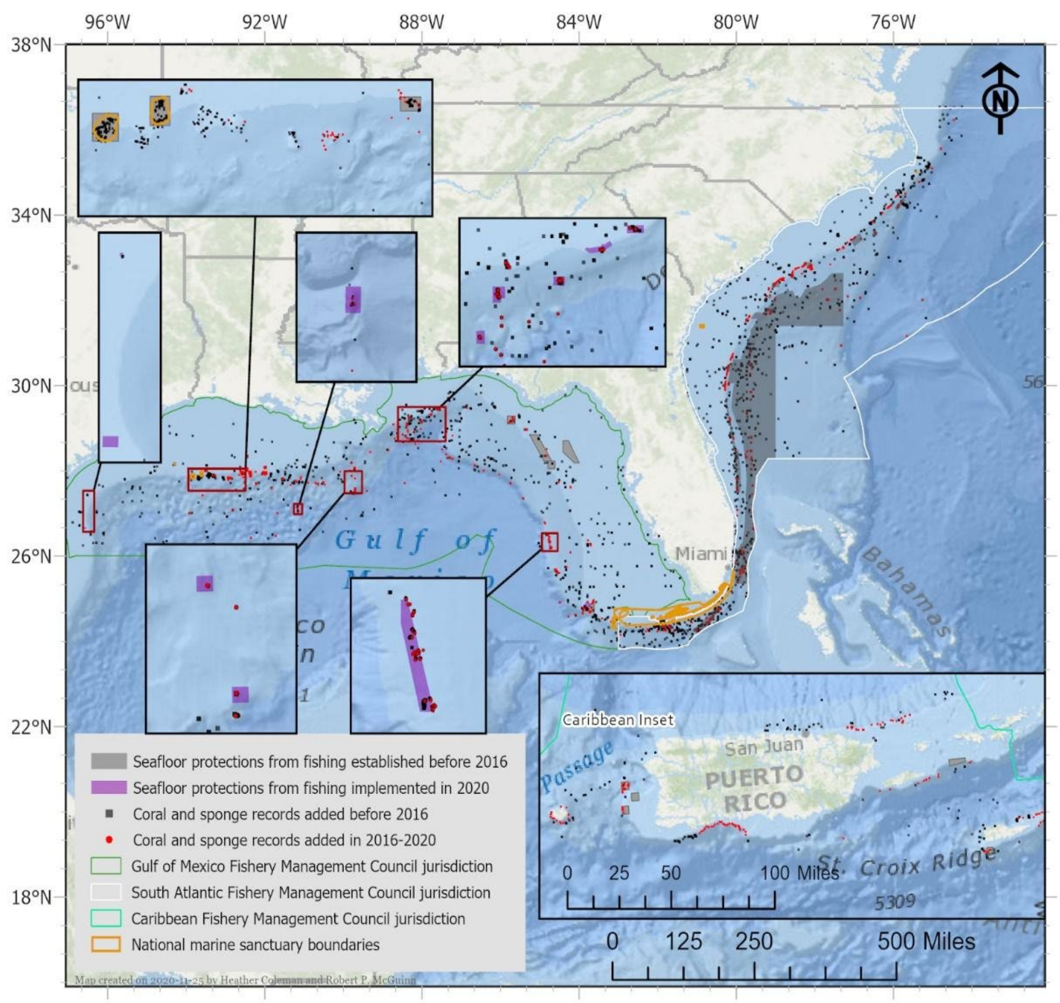

Figure 58. Restrictions from seafloor trawling (and in some cases, other types of seafloor-contact fishing as well) established before SEDCI began in 2016 (gray polygons) and in 2020 (purple polygons). Deep-sea coral and sponge records added to the National Database before SEDCI (black squares) and during the SEDCI timeframe (red circles). Note that records added between 2016-2020 include both new discoveries by SEDCI researchers and data analyzed ("rescued") by the SEDCI team that would not otherwise have been incorporated into the National Database.

8. Future Considerations

8.1 Suggestions for Future Implementation/Administration

The timeline for the suggestions that follow may be near future or long-term. Certain amendments, expansions, and other activities will expedite some of the suggestions.

Data Analysis and Site Characterization

- Support analysis of SEDCI and other coral, sponge, and fish data records in order to assess interactions between federally-managed fisheries species of concern (e.g., warsaw grouper, speckled hind, etc.) and coral habitat.
- Support data analysis, fine scale species distribution modeling, and site characterizations beginning with priority areas including Oculina Bank HAPC areas proposed for reopening to rock shrimp fishing, the western edge of Stetson/Miami Terrace and Pourtalès Terrace Coral HAPCs, and the Blake Plateau off the Southeast U.S. coast.
- Identify and characterize habitat for echinoderms, crustaceans, and other invertebrates and their association with deep coral and sponge habitats in all three SEDCI regions.
- Mine historic data for information on species and habitats of interest (i.e., keystone or foundation indicator species for ocean acidification and climate change), fish populations and Essential Fish Habitat, and marine debris.
- Promote analysis of gear interaction and impacts to enhance annotations and analyses that have already been provided.
- Support development of machine learning and new techniques that would use existing video, images, and annotations, and eventually live survey annotation of taxa and habitat types.

Informing Protected Area Delineation

- Provide observations of high-density deep coral areas not already within designated boundaries to support decisions regarding boundaries changes that can enhance protection from bottom-disturbing activities. Observations also support decisions regarding oil and gas activities provided through Bureau of Ocean Energy Management No Activity Zones and areas identified in the Biologically-Sensitive Underwater Features and Areas Notice to Lessees (No. 2009-G39).
- Identify criteria for characterizing and delineating areas of high-density deep coral and sponge communities found in the SEDCI regions, particularly in areas of potential anthropogenic impact.
- Provide data, information, and analyses to support the Gulf of Mexico Fishery Management Council in development of planned Amendment 10 to the Coral and Coral Reef Resources Fishery Management Plan for U.S. Gulf of Mexico waters.
- Provide data, information, and analyses to support the South Atlantic Fishery Management Council in development of planned Amendment 11 to the Coral, Coral Reefs and Live/Hard Bottom Habitat Fishery Management Plan for U.S. South Atlantic waters.
- Provide relevant data for future national marine sanctuary expansions in deep water, such as for the Florida Keys National Marine Sanctuary.

Monitoring

- Support monitoring activities in newly designated Gulf of Mexico HAPCs, FGBNMS expansion areas, MPAs, and other protected areas in all SEDCI regions.
- Highlight the importance of monitoring reefs and banks to understand changes in the environment and health of benthic communities. External projects such as the Natural

Resource Damage Assessment - Deepwater Horizon Mesophotic and Deep Benthic Communities project may be able to support this effort long-term.

8.2 Priorities for Future Research

Mapping, Modeling and Remote Sensing

- Mapping and benthic survey work in the U.S. Caribbean region, including participating in planning and supporting upcoming OER expeditions in this region.
- Targeted mapping and data collection to validate existing habitat suitability models.
- Collecting and processing backscatter data in future mapping efforts in support of future predictive habitat modelling efforts.
- Analyzing remote sensing derivation of ocean chemistry or productivity for areas of high diversity and density of organisms. In situ data or localized photogrammetry could also inform these analyses.
- Modeling potential changes in coral species distributions under future climate change scenarios (IPCC, 2021).
- Creating regional mapping and data inventories with online sharing tools to enhance coordination of cross-project collaborations.

Sampling

- Targeted sampling of corals and sponges for genetic/morphological analyses to increase understanding of taxonomy, connectivity, and population dynamics, as well as to contribute data and samples in support of environmental DNA and biomedical analyses.
- Targeted sampling of lace corals and black corals to better understand climate change impacts to deep corals and associated communities through radio-isotopic analyses and studies of age and growth (e.g., Stewart et al., 2020; Prouty et al., 2011).

Other Research

- Examine physical, organismal, and genetic connectivity among newly designated Gulf of Mexico HAPCs and FGBNMS expansion areas using acoustic telemetry, ocean current models, and genomics.

2016-2019 SEDCI science priorities that were not addressed

- Caribbean region: What are the most significant anthropogenic impacts to deep-sea coral and sponge ecosystems, particularly at mesophotic depths?
- Southeast U.S. region: What drives community structure differences between sites?
- Southeast U.S. region: How are populations connected and what factors shape genetic connectivity?
- Southeast U.S. region: What interactions (past, present, and future) occur between fishing gear (e.g., golden crab, rock shrimp, royal red shrimp, and wreckfish) and deep-sea coral and sponge environments?
- Southeast U.S. region: Do upwelling and variability in other ocean conditions impact communities?

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9. Manuscripts, Reports and Digital Resources produced by SEDCI

9.1 Peer-Reviewed Journal Articles

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Howell KL, Davies JS, Allcock AL, Braga-Henriques A, Buhl-Mortensen P, et al. (2019) A framework for the development of a global standardised marine taxon reference image database (SMarTaR-ID) to support image-based analyses. PLoS ONE 14(12): e0218904. doi.org/10.1371/journal.pone.0218904

Netburn, AN, C Adams, P Etnoyer, J Murphy, K Cantwell. 2019. Turning the Lights on for Deep-Sea Ecosystems in the Caribbean, Gulf of Mexico, and US Southeast Atlantic. Limnology and Oceanography Bulletin. Vol 28, Issue 3, pp 109-110 aslopubs.onlinelibrary.wiley.com/doi/full/10.1002/lob.10329?af=R

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Sterne, TK, Retchless, D, Allee, R, Highfield, W. Predictive modelling of mesophotic habitats in the north-western Gulf of Mexico. *Aquatic Conserv: Mar Freshw Ecosyst*. 2020; 30: 846–859. doi.org/10.1002/aqc.3281

Wagner, D., and A. Shuler. 2017. The black coral fauna (Cnidaria: Antipatharia) of Bermuda with new records. Zootaxa, 4344(2):367-379. doi:10.11646/zootaxa.4344.2.11

Walker, Brian K., Charles Messing, Jana Ash, Sandra Brooke, John K. Reed, Stephanie Farrington, Regionalization of benthic hard-bottom communities across the Pourtalès Terrace, Florida, Deep Sea Research Part I: Oceanographic Research Papers, Volume 172, 2021, 103514, ISSN 0967-0637, https://doi.org/10.1016/j.dsr.2021.103514

9.2 NOAA Technical Memoranda

Battista. T., Shuler, A., Taylor, C., Kraus, J., Bassett, R., Salgado, E., Etnoyer, P. (2020). Cruise Report for NOAA Ship *Nancy Foster* NF-19-01: Mapping Essential Fish Habitat in the US Caribbean to Inform MPA Management (2019). NOAA Technical Memorandum NOS NCCOS 274. Silver Spring, MD. 102 pp. repository.library.noaa.gov/view/noaa/25356

Blakeway, R., E. Hickerson, et al. (Anticipated 202X). Site characterization report for Flower Garden Banks Expansion areas, results from benthic surveys using an ROV in years 2016-2018.

Nizinski, M and M Rhode. (Anticipated 202X) Site characterization and dive summary reports for Southeast US submarine canyon explored in years 2016 - 2017 - Hatteras, Pamlico, and Keller Canyons.

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Wagner D, Etnoyer PJ, Schull J, David AW, Nizinski MS, Hickerson EL, Battista TA, Netburn AN, Harter SL, Schmahl GP, Coleman HM & Hourigan TF (2017). Science Plan for the Southeast Deep Coral Initiative (SEDCI): 2016-2019. NOAA Technical Memorandum NOS NCCOS 230, NOAA National Ocean Service, Charleston, SC 29412. 96 pp. repository.library.noaa.gov/view/noaa/14167

9.3 Poster Presentations

Freeman, J., and A. Skarke (Anticipated 2022) Geospatial analysis of deep-sea benthic environments through application of the Coastal and Marine Ecological Classification Standard to ROV video data. To be presented at the 2022 Ocean Sciences Meeting, 27 Feb-04 Mar.

Hourigan, T, RP McGuinn, PJ Etnoyer, D Wagner, M Dornback, MD Poti, HM Coleman. 2018. Deep-Sea Corals of the Southeast U.S.: Insights from NOAA's National Database of Deep-Sea Corals and Sponges. Ocean Sciences Meeting. San Diego, CA. LINK

Will, Morgan. Diversity and Abundance of Deep-Sea Corals and Sponges in the Bathyal Terrain of West Florida Escarpment. NOAA Mission Goal: Healthy Oceans. Poster presented at the Ocean Sciences Meeting, Feb 16-21, 2020, San Diego, CA.

9.4 Outreach

Etnoyer, PJ, M Malik, D Sowers, C Ruby, R Bassett, J Dijkstra, N Pawlenko, S Gottfried, K Mello, M Finkbeiner, and A Sallis. 2018. Working with video to improve deep-sea habitat characterization. In Raineault, N.A, J. Flanders, and A. Bowman, eds. 2018. New frontiers in ocean exploration: The E/V *Nautilus*, NOAA Ship *Okeanos Explorer,* and R/V *Falkor* 2017 field season. *Oceanography* 31(1), supplement, 126 pp., doi.org/10.5670/oceanog.2018.supplement.01

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9.5 Academic Theses

Freeman, J. (2022) Geospatial analysis of deep-sea benthic environments through application of the Coastal and Marine Ecological Classification Standard to ROV video data. Masters Thesis: Mississippi State University, Mississippi State, MS, USA. *Anticipated*

Nuttall, M.F., Opresko, D.M. and Hickerson, E.L., 2016. Validation of Image-Based Species Identifications of Black Corals (Order Antipatharia) on Mesophotic Rocks. *Gulf of Mexico Science*, *33*(1), p.3. doi.org/10.18785/goms.3301.03

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Proux, Zachary Samuel (2018) Assessing the Relationship between Geomorphology and Deep-Sea Megafaunal Communities on the West Florida Escarpment." Masters thesis at College of Charleston. repository.library.cofc.edu/handle/123456789/3720

Sowers, Derek C., "Utilizing Extended Continental Shelf (ECS) and Ocean Exploration Mapping Data for Standardized Marine Ecological Classification of the U.S. Atlantic Margin" (2020). *Doctoral Dissertations*. 2556. https://scholars.unh.edu/dissertation/2556

Sterne, Travis. "Predictive Modeling of Mesophotic Habitats in the Northwestern Gulf of Mexico" Masters thesis at Texas A&M Galveston, 2018. hdl.handle.net/1969.1/173740

Yeckley, Sean Paul. (2017) "Temporal trends in abundance and habitat preferences of deep reef fishes off the coast of South Carolina, USA." Masters thesis at Savannah State University. hdl.handle.net/11286/620752

9.6 Digital Resources

9.6.1 Online Geodatabase

Dorfman, D, J. Howell, A. Shuler, H. Burkart, K. Miller. 2019. Southeast Deep-Sea Coral Digital Atlas. NOAA National Centers for Coastal Ocean Science. LINK

9.6.2 Photo ID Guides (*also listed in NOAA technical memoranda above)

Salgado EJ and Etnoyer PJ (2020). Photographic catalog of deep-sea corals collected from the US West Atlantic margin by NOAA Ship *Okeanos Explorer* in years 2017- 2019. NOS NCCOS 273. 132 pp. doi.org/10.25923/nnny-st44

Shuler AJ and PJ Etnoyer. (2020) Alcyonacean octocorals of the Pinnacle Trend: A photo-identification guide. NOAA Technical Memorandum NOS NCCOS 282. 56 pp. doi:10.25923/xzd1-z382

9.6.3 Data Dashboards

For each dataset that SEDCI contributed to the NOAA Deep Sea Coral Research and Technology Program data portal there is a "data dashboard" with all the details of that dataset. Each Dataset ID below links to the appropriate data dashboard.

DataProvider	DatasetID	PI	DataContact	Reporter	n
MacDonald, Ian Silva, Mauricio	USGS_TM-97-10	MacDonald, Ian	MacDonald, Ian: imacdondald@fsu.edu	Silva, Mau	901
Sharuga (2014)	Sharuga_SM_2014	Benfield, Mark	Sharuga, Stephanie: ssharuga@outlook.com	Sharuga, Stephanie	125
NOAA, Deep Sea Coral Research and Technology Program	NOAA_SJ-09-08	Ross, Steve W.	Ross, Steve: rosss@uncw.edu	Hourigan, Tom	2,859
Harbor Branch Oceanographic Institute	NOAA_SJ-05-11, NOAA_SJ-07-05, NOAA_SJ-05-10, HBOI_SJ-10-07, NOAA_NF-11-09, NOAA_NF-11-09-L3, NOAA_PC-11-05-L1, HBOI_EL-99-08, NOAA_SJ-02-08, NOAA_RB-03-07, NOAA_SJ-04-05, NOAA_SJ-05-04, NOAA_SJ-05-08, HBOI_SJ-06-02, HBOI_SJ-06-05-L1, HBOI_SJ-06-05-L3, NOAA_SJ-07-06, NOAA_SJ-09-08, HBOI_SJ-88-11, HBOI_SJ-08-09, HBOI_WS-17-125, NOAA_PC-12-03, NOAA_PC-13-03, NOAA_NF-14-08, NOAA_PC-15-02, NOAA_PC-16-02, NOAA_PC-17-02	Brooke, Sandra D., Messing, Charles G., Ross, Steve W. | Nizinski, Martha S. | Morrison, Cheryl L., Reed, John | Rogers, Stephanie, Reed, John, David, Andrew W., Harter, Stacey: stacey.harter@noaa.gov	Brooke, Sandra, Ross, Steve: rosss@uncw.edu, Reed, John: jreed12@fau.edu	Hourigan, Tom, Dubick, JD, Farrington, Stephanie, Reed, John	27,835
NOAA RESTORE Program	NOAA_RESTORE_MT18	Herrera, Santiago	Herrera, Santiago: santiago.herrera@lehigh.edu	Frometa, Janessy	253
NOAA, Southeast Fisheries Science Center	NOAA_PC-11-05-L1	NA	Harter, Stacey: stacey.harter@noaa.gov	Hourigan, Tom	2
NOAA, Gray's Reef National Marine Sanctuary	NOAA_PC-10-02	Sedberry, George	Sedberry, George: george.sedberry@noaa.gov	Yeckley, Sean | Sedberry, George	773
NOAA, National Centers for Coastal Ocean Science	NOAA_NF-17-08, NOAA_NF-18-04, NOAA_NF-19-01	Etnoyer, Peter, Battista, Tim | tim.battista@noaa.gov,	Etnoyer, Peter: peter.etnoyer@noaa.gov, Battista, Tim	Proux, Zach, Shuler, Andrew	9,124
NOAA, Coral Reef Conservation Program	NOAA_NF-14-01, NOAA_NF-12-01, NOAA_NF-13-02	Battista, Tim	Battista, Tim: tim.battista@noaa.gov	Battista, Tim	1,082

NOAA, Center for Coastal Monitoring and Assessment	NOAA_NF-05-05, NOAA_NF-07-06, NOAA_NF-08-04, NOAA_NF-09-01	Battista, Tim	Battista, Tim: tim.battista@noaa.gov	Shuler, Andrew	497
Pennsylvania State University	NOAA_HC-11-10, OET_NA028, OET_NA057, SOI_FK006B, OET_NA043, ECOGIG_OI-16-10, OET_NA058, ECOGIG_O2-17-06, BOEM_Lophelia_II, WHOI_AT-18, NOAA_EX-12-02-L2	Fisher, Charles R., Cordes, Erik	Fisher, Charles: fisher@psu.edu, Fisher, Charles: cfisher@psu.edu	Frometa, Janessy	1,087
NOAA, Office of Ocean Exploration and Research	NOAA_EX-12-02-L2, NOAA_EX-17-11, NOAA_EX-18-03, NOAA_EX-18-06, NOAA_EX-15-02-L3, NOAA_EX-18-11, NOAA_EX-19-03-L2, NOAA_EX-19-07	Lobecker, Elizabeth, Amon, Diva | Messing, Charles, Wagner, Daniel | Skarke, Adam, Morrison, Cheryl | Sautter, Leslie, Kennedy, Brian, Auscavitch, Steve | Williams, Stacy, Wagner, Amy | Weinnig, Alexis, Farrington, Stephanie | Galvez, Kimberly	Etnoyer, Peter: peter.etnoyer@noaa.gov, Bassett, Rachel: rachel.bassett@noaa.gov, Bassett,Rachel; rachel.bassett@noaa.gov, Gugliotti, Elizabeth: elizabeth.gugliotti@noaa.gov , Etnoyer, Peter | peter.etnoyer@noaa.gov, Salgado, Enrique: enrique.salgado@noaa.gov, Bassett, Rachel | rachel.bassett@noaa.gov	Dubick, JD, Bassett, Rachel, Gugliotti, Elizabeth, Shuler, Andrew, Salgado, Enrique, Frometa, Janessy	17,491
NOAA, Flower Garden Banks National Marine Sanctuary	NOAA_DFH-30, NOAA_DFH-32-33, NOAA_FGBNMS_DFH-35, NOAA_FGBNMS_DFH-37	Nuttall, Marissa, Stern, Travis, Hickerson, Emma	Sterne, Travis: travis.sterne@noaa.gov, Walker, Raven: raven.walker@noaa.gov, Blakeway, Raven: raven.walker@noaa.gov	Sterne, Travis, Blakeway, Raven	7,351
Brooks et al. (2016)	BOEM_Lophelia_II	Cordes, Erik, Fisher, Charles R., Ross, Steve W.	Fisher, Charles: cfisher@psu.edu | Cordes, Erik: ecordes@temple.edu	Wickes, Leslie	2,546
Bureau of Ocean Energy Management	BOEM_Lophelia_II	Fisher, Charles R., Cordes, Erik	Fisher, Charles: cfisher@psu.edu | Cordes, Erik: ecordes@temple.edu, Brooks, James: drjmbrooks@aol.com, Etnoyer, Peter: peter.etnoyer@noaa.gov, Quattrini, Andrea: aquattrini@g.hmc.edu	Fowle, Holly, Quattrini, Andrea, Salgado, Enrique	1,195
Temple University	BOEM_Lophelia_II	Cordes, Erik, Fisher, Charles R., Ross, Steve W., MacDonald, Ian	Cordes, Erik: ecordes@temple.edu	Wickes, Leslie	8,344

9.6.4 NOAA Deep Sea Coral Research and Technology Program Data Portal

deepseacoraldata.noaa.gov/

9.6.5 SEDCI Overview and Project Pages

NOAA NCCOS. 2016. Southeast Deep Coral Initiative (SEDCI): Exploring Deep-Sea Coral Ecosystems off the Southeast U.S. NCCOS News Article. LINK

NOAA NMFS. 2016. Southeast Deep Coral Initiative (SEDCI): Exploring Deep-Sea Coral Ecosystems off the Southeast U.S. LINK

9.6.6 SEDCI Area of Interest Report from the NOAA National Database

The report below will be online at the DSCRTP data portal SEDCI project page HERE after publication of this report.

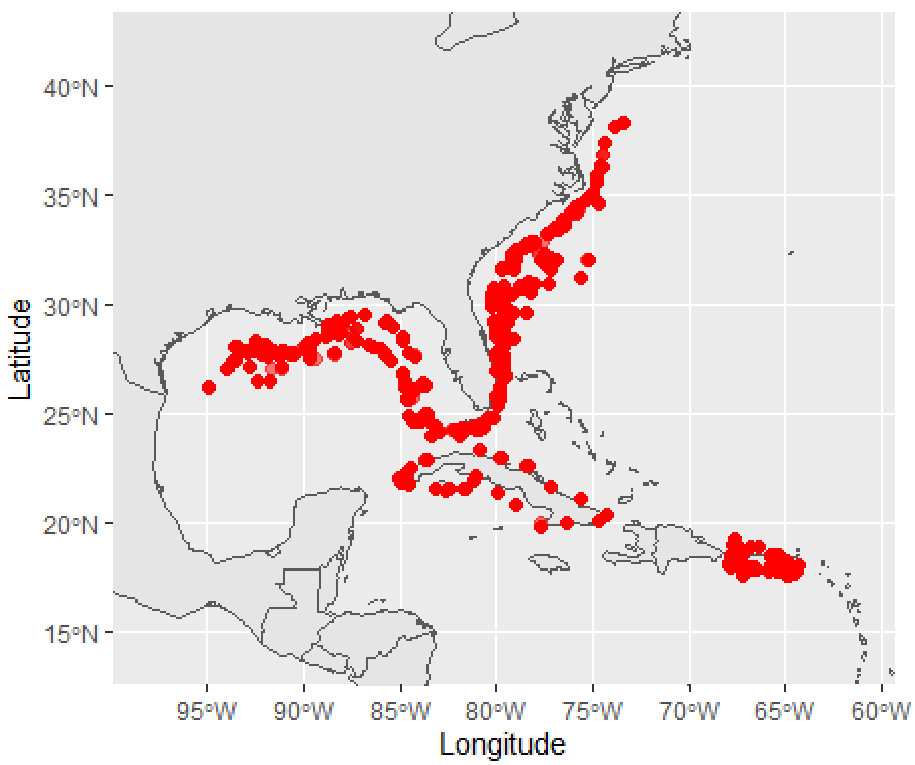
NOAA National Database for Deep-sea Corals and Sponges: Area of Interest Report for SEDCI

NOAA-NFMS-OHC-DSCRTP

Robert.McGuinn@NOAA.gov; 843-460-9696. Report last ran: 2021-06-16

Database Version DSCRTP_NatDB_20210412-0

Area of Interest Map



3D Bounding Box

```
##                   min      max
## Longitude     -94.868  -64.329
## Latitude       17.590   38.322
## DepthInMeters   2.000 4991.000
```

Summary of this Area of Interest by the Numbers

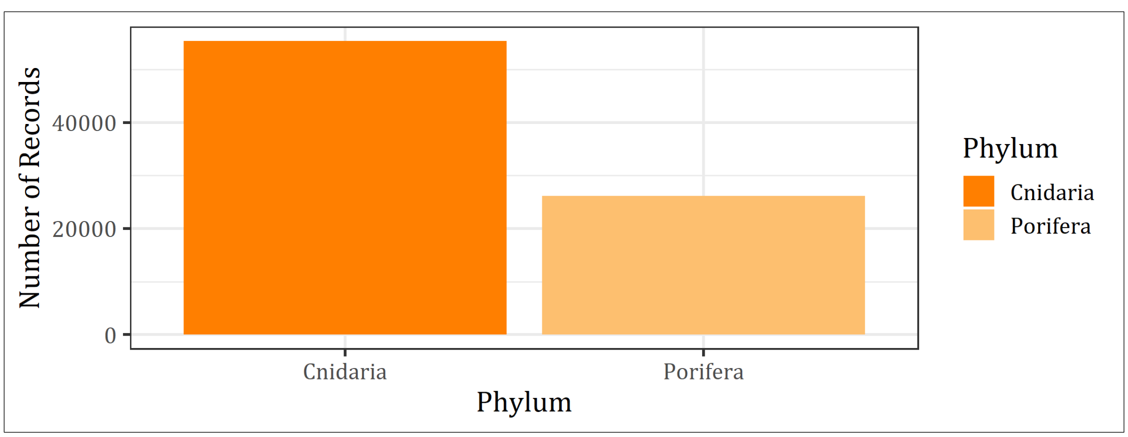
Note: The numbers below only reflect published records. Additional records may be retained by DSCRTP for further review.

- **Number of records:** 81,465
- **Number of coral records:** 55,340
- **Number of sponge records:** 26,125
- **Records with images:** 51,123
- **Record type(s):** video observation, still image, specimen, video and still images, still image | specimen, still image | video observation, video observation | specimen
- **Minimum depth (meters):** 2
- **Maximum depth (meters):** 4,991
- **Time frame:** 1988 to 2020

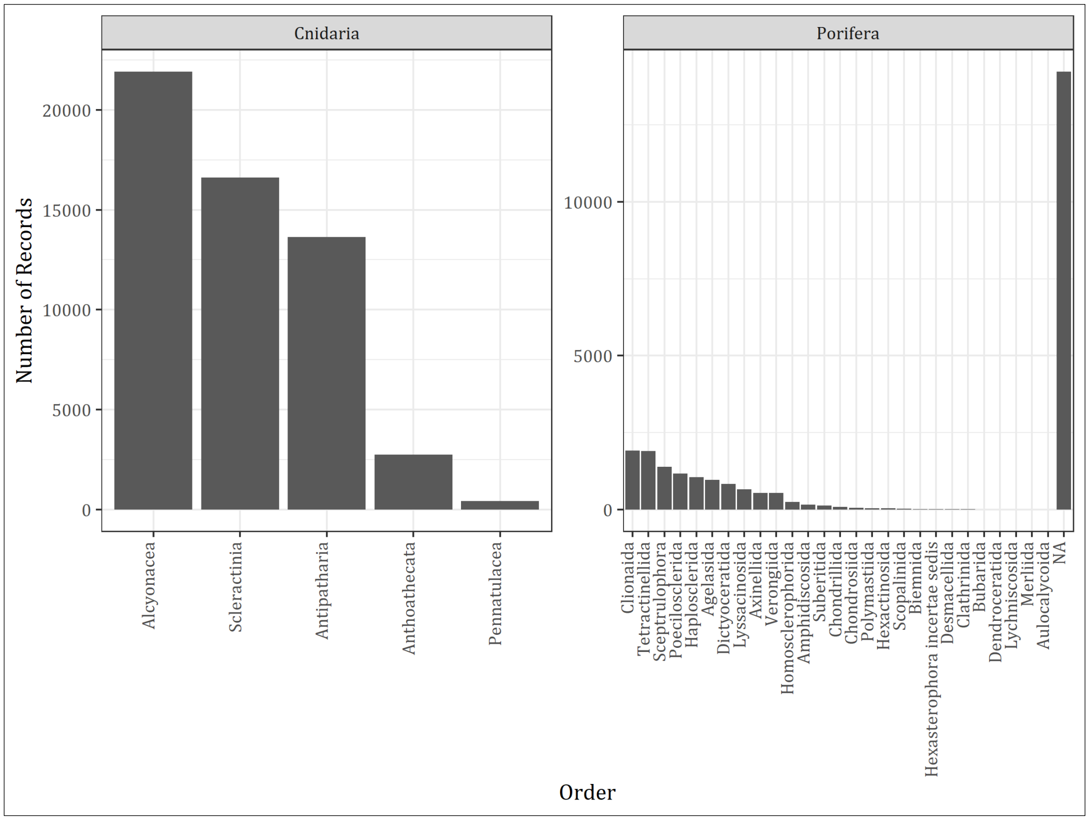
Where?

Country	Ocean	Fishery Management Council Region	n
USA	North Atlantic	South Atlantic, Gulf of Mexico, Caribbean, Mid-Atlantic	76,913
Cuba	North Atlantic	NA	4,541
Dominican Republic	North Atlantic	NA	7
Bahamas	North Atlantic	NA	4

Corals (cnidaria) and sponges (porifera)



Distribution of Taxa by Order



10. Budget

10.1 Budget Overview

Leveraged funding played a large role in SEDCI projects. For example, NOAA Ship *Okeanos Explorer* expeditions and R/V *Atlantis* and AUV *Sentry* operations were funded by several cross-agency organizations, including the NOAA National Centers for Coastal Ocean Science, NOAA Office of Ocean Exploration and Research, and NOAA Fisheries Southeast Fisheries Science Center. BOEM-funded modeling efforts also benefitted from SEDCI analyses.

Small projects and other field work were supplemented by funds from NOAA Coral Reef Conservation Program, South Atlantic Fishery Management Council, Bureau of Ocean and Energy Management, NOAA Regional Geospatial Modeling Grant (NOAA Office of Coastal Management), NOAA Fisheries Cooperative Research Program, Hollings Marine Scholar Program, NOAA Fisheries Office of Science and Technology, NOAA Flower Garden Banks National Marine Sanctuary, Consolidated Safety Services, Inc., and the National Marine Sanctuary Foundation.

10.2 Budget Breakdown

A breakdown of the 2016-2019 SEDCI expenditures is provided below, which includes overall funds for small projects and fieldwork discussed in this report. Table 10 shows the cost allocations represented as proportions in Figure 59. The funding is also shown by region and by receiving agency in Figures 60 and 61. Funding amounts include salaries, supplies and equipment, mapping, ship time, ROV time and staff, travel, conference fees and publication fees.

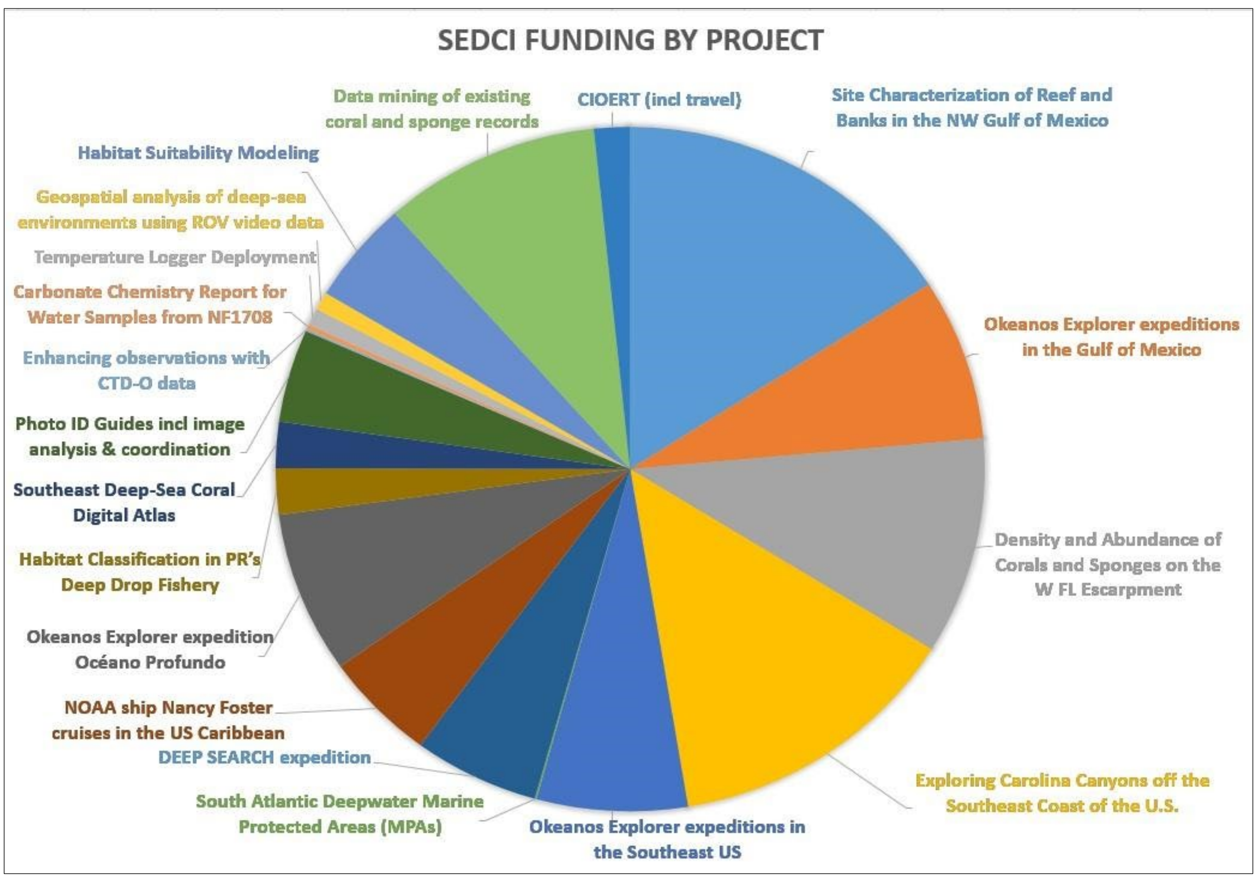


Figure 59. A proportional breakdown of SEDCI expenditures by fieldwork and small projects.

Table 10. A numeric representation of SEDCI expenditures by fieldwork and small projects, region and receiving agency.

Project	SEDCI funding	Region	Agency/ Office
Site Characterization of Reef and Banks in the NW Gulf of Mexico	$417,000	GoM	ONMS
NOAA Ship *Okeanos Explorer* expeditions in the Gulf of Mexico	$200,000	GoM	OER
Density and Abundance of Corals and Sponges on the West Florida Escarpment	$268,500	GoM	NCCOS/ NMFS/Other
Exploring Carolina Canyons off the Southeast Coast of the U.S.	$355,000	SEUS	NMFS
NOAA Ship *Okeanos Explorer* expeditions in the Southeast U.S.	$180,000	SEUS	OER
South Atlantic Deepwater Marine Protected Areas	$2,000	SEUS	NMFS
DEEP SEARCH expedition	$150,000	SEUS	OER
CIOERT including travel	$42,900	SEUS	Other
NOAA Ship *Nancy Foster* cruises in the U.S. Caribbean	$135,000	Carib	NCCOS
NOAA Ship *Okeanos Explorer* expedition Océano Profundo	$200,000	Carib	OER
Habitat Classification in Puerto Rico's Deep Drop Fishery	$57,000	Carib	NMFS
Southeast Deep-Sea Coral Digital Atlas	$57,109	SEUS	NCCOS
Photo ID Guides including image analysis and coordination	$115,000	GoM/SEUS	NCCOS
Enhancing observations with CTD-O data	$2,495	GoM	NCCOS
Carbonate Chemistry Report for Water Samples from NF1708	$6,000	GoM	Other
Temperature Logger Deployment	$21,000	GoM/Carib	NCCOS
Geospatial analysis of deep-sea environments using ROV video data	$22,282	All	Other
Habitat Suitability Modeling	$127,000	All	NCCOS
Data Mining of existing coral and sponge records	$259,600	All	Other

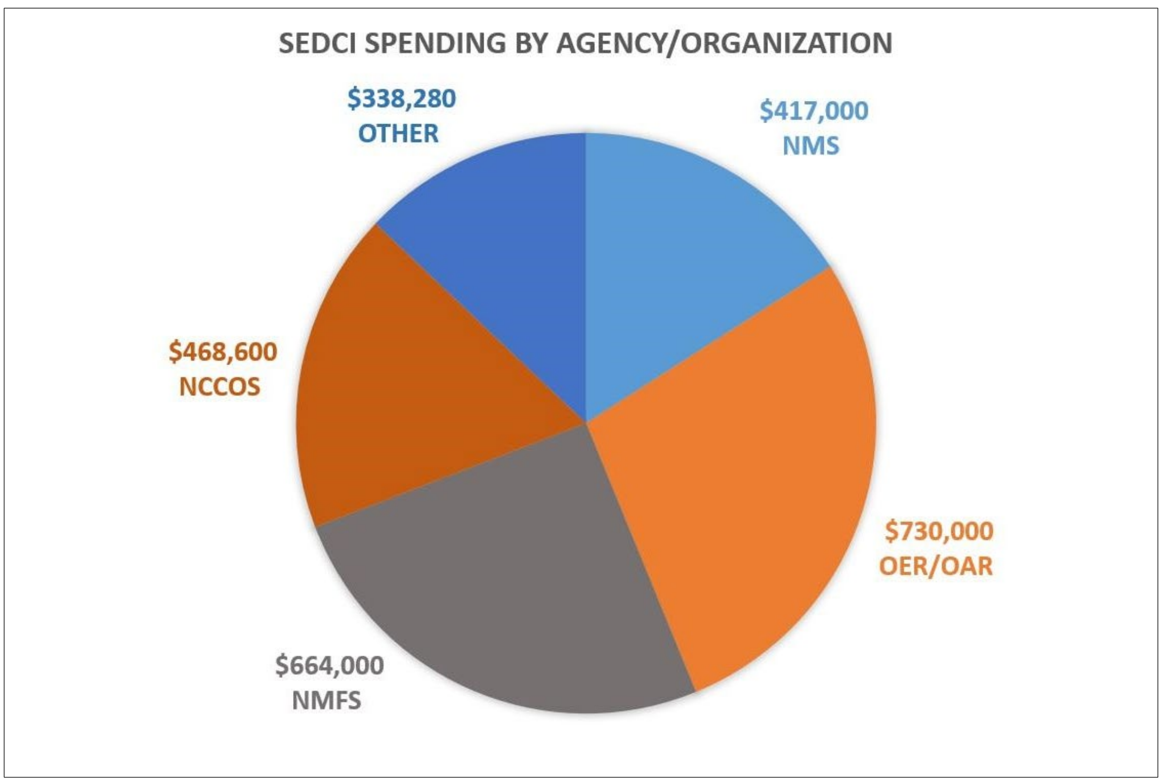


Figure 60. A breakdown of SEDCI expenditures by the amount of funds provided to each NOAA agency. "Other" includes non-NOAA organizations such as USGS, and numerous academic institutions funded through NOAA Cooperative Institutes.

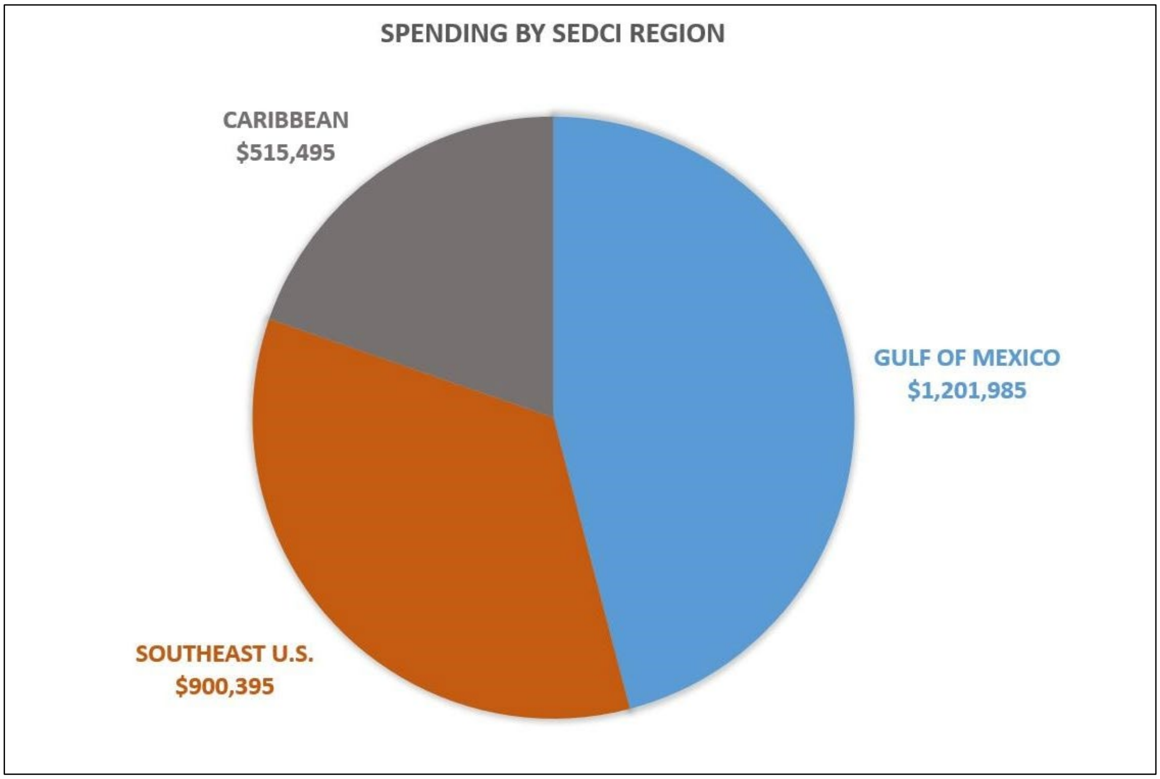


Figure 61. A breakdown of expenditures by SEDCI region.

United States Department of Commerce

Gina M. Raimondo

Secretary of Commerce

National Oceanic and Atmospheric Administration

Richard Spinrad

Administrator

National Marine Fisheries Service

Janet Coit

Assistant Administrator